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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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SEDIMENT CONTROL WITH MAXIMUM RESOURCE USE--
A CHALLENGE TO WILDLAND RESEARCH

The Intermountain region embraces a total land area of about 175 million acres. All but a few million of these acres are forest and range lands. These wildlands are covered for the most part by a mantle of soil and weathered rock material to depths that range from a few inches to many feet. Much of this material--probably several hundred million acre feet of it--is situated on slopes above communities, farms and factories, and above the roads, canals, and reservoirs which serve those developments.

The possibility of removal of this mantle from the forest and range lands by running water with subsequent deposition in downstream developments is by all odds the greatest menace to the economy of the region. Range livestock production, timber production, hunting and recreation--all major enterprises in this region--could not survive if the productivity of the wildlands were ruined by erosion. Neither could agricultural, industrial, or community enterprises survive if the farms, factories, and homes as well as the roads and water facilities upon which they are dependent were buried in sediments washed from the lands above.

Danger of such destruction is not of concern solely to future generations. Accelerated erosion, abnormal flooding and excessive sedimentation have already exacted a serious toll. Few, if any, drainage basins have escaped some degree of soil loss and in numerous places these losses include virtually all of the top soil. Moreover, summer storm debris-floods of unprecedented violence in historic times have become a common event in recent years.

Some of the soil and rock material that has been eroded from formerly stable slopes and valley bottoms together with the normal sediment load of streams, has already displaced irreplaceable storage in reservoirs. Some has been diverted into irrigation systems, requiring costly cleaning operations. Some has lodged in channels where it is increasing the frequency and magnitude of floods.

More sediments are on the move in upstream channels. What is more serious, an enormous quantity of additional material that is still intact on the watershed lands is bound to be displaced and added to the sediment load of streams unless the currently speeded up forces of degradation are brought under control. Herein lies a challenge to research in wildland management.

The causes of watershed impairment and the general principles of restoring and maintaining wildlands have been established by experience and scientific experimentation. It is known that deterioration starts when fire, overgrazing, destructive logging, or other disturbance reduces the capacity of a site to infiltrate and store precipitation, thus allowing surface runoff and soil erosion to take place. It is also known that the restoration and maintenance of a plant cover and soil mantle having a capacity for coping with the vicissitudes of climate equal to that which had been developed over the ages in a basic requirement for effective wildland management.

Notwithstanding a growing accumulation of knowledge about the forest range land resources of this region, many difficult problems remain to be solved. One group of these problems centers around the lack of knowledge as to how to restore deteriorated forest and range land. Another involves the equally difficult task of determining specifically how and to what extent these lands can be utilized without impairing either their productivity or watershed functions.

During the past year, some progress has been made toward finding methods of restoring impaired forest and range land. Some progress has also been made toward determining the requirements for maintaining satisfactory watershed conditions under the impact of various uses such as timber harvesting, grazing, etc. The current accomplishments of research toward these goals and the plans for further research during the coming year are given under the Divisional headings which follow.

WATERSHED MANAGEMENT AND PROTECTION

Further progress was made toward the solution of sedimentation, flood, and water supply problems during the past year through renewal of influences investigations at the Boise Research Center and continuation of work at the Wasatch and the Great Basin Research Centers. Major emphasis at all three of the research centers was placed on investigations of soil stability. These studies were supplemented by related investigations of the effects of plant cover on stream flow, on water losses, and on snow accumulation and melting.

Soil Stabilization

How to restore and maintain the normal stability of soil on watershed slopes and at the same time allow for utilization of forage and timber resources continues to be the major watershed research problem in the region. Growing deposits of sediments in reservoirs, shoaled channels, increased frequency and violence of summer debris-floods, newly trenched valley fill, and freshly incised gullies on watershed slopes all attest to excessive storm flows and quickened rates of erosion. These manifestations reflect a woefully inadequate understanding of the requirements for designing effective watershed management.

Through past research it has been definitely established that high intensity rainfall and the condition of the plant and soil mantle with respect to normal are the two primary factors of major importance affecting the stability of soil on watershed slopes. Summer "cloudburst type" rainfall is of critical importance because the large drops and great impact that generally characterize such rains are highly effective in detaching soil particles and in setting them in motion downhill. Another critical feature of these rains is the high intensities that are attained for brief periods. Anything less than the normal plant cover and soil mantle is also important because such conditions lessen the capacity of a site to contain rainfall and thereby increase the chances for overland flow and the removal of soil. However, the characteristics of summer storms and the watershed conditions that are required for coping with them are as yet not fully understood. Last year, therefore, several studies were made to obtain further information about these critical factors.

Summer storm characteristics

Just as an architect needs to know the maximum probable snow load for designing a safe building, so also do watershed managers need to know the intensity-duration pattern and recurrence interval of the greatest probable rainfall to which a watershed area may be subjected. In 1935 a network of rain gages was established on the Wasatch Experimental forests covering an area of about 20,000 acres. An analysis of the records from these gages revealed some new facts on rainfall characteristics of that area.

During the period 1935-47 inclusive, 153 rainstorms were recorded in the months of July and August at a rain gage in the head of Parrish Creek at an elevation of 8,300 feet. All but 10 of these rains totalled less than 0.50 inch, 114 of them amounting to less than 0.25 inch. Seven of the rains were between 0.51 and 1.00 inch in volume, and three others had volumes between 1.01 and 1.25 inches. These are but minor storms as compared to the deluges that are common in the more humid regions of the nation. Their potency as flood producers becomes clear, however, when their intensity characteristics are understood.

Rainfall intensity records were obtained for 136 of the 153 summer storms at the Parrish station. Of these recorded storms, 125 produced rainfall rates of less than 2.00 inches per hour for 5 minutes, 103 of them producing rates of less than 1.00 inch per hour. None of these storms caused any measurable runoff or soil loss from plots that were sparsely covered with vegetation and characteristic of typical flood-source conditions.

Small amounts of runoff and soil loss were caused by 12 other storms which developed maximum rainfall rates of between 2.00 and 3.00 inches per hour for 5 minutes. Assuming this to be an average period of record, it is evident that deteriorated portions of watersheds, on the average, will lose some soil each year as the result of such moderate storms.

The damage caused by rains of moderate intensity--though serious because of their cumulative effect--is dwarfed by the effects of a few storms of high intensity. Three such rains were recorded at the Parrish gage in the 12-year period of record. These attained maximum rates of between 4.00 and 5.00, 5.00 and 6.00, and 6.00 and 7.00 inches per hour for periods of 5 minutes. Two other rain gages in the network have recorded rates equal to and one other has recorded an even greater rate than the maximum thus far recorded at the Parrish gage. The maximum rate thus far recorded was registered in a Farmington Canyon gage on August 10, 1947. This rate was 8.44 inches per hour, which is about twice the maximum intensity thus far reported by a Weather Bureau station in Utah.

The most outstanding characteristic of these major storms is that generally more than 40 percent and sometimes as much as 70 percent of the total rainfall occurs within a 5-minute period. Comparison of synchronized records from gages spaced at about 1/2 mile intervals across the 6-mile front of the experimental watersheds also show that the major "bursts" at the several stations generally occur within 30 minutes of each other. These records show further that all of the major storms produced rainfall rates in excess of 2.50 inches per hour over an area of at least 20 square miles.

The three high intensity rains described above removed up to 192 cubic feet of soil per acre from sparsely covered "flood source" plots. Each of these storms also caused mud-rock floods in nearby deteriorated watersheds. They failed, however, to cause either runoff or soil loss from well covered aspen and reseeded grass plots or to produce floods from watersheds in which previously deteriorated, flood-source areas had been improved by contour trenching, reseeding and protection from fire and overgrazing.

These rainfall records and the measured runoff and erosion behavior of watershed sites leave no room for doubt that man can cause floods in this area by destroying the plant cover on watershed lands. The recording of three cloudburst storms of flood-producing magnitude in the short period of 12 years also emphasizes the high flood hazard that can be developed on the steep mountains of northern Utah when the plant cover and soil mantle on the watershed lands are allowed to be damaged.

Sedimentation potentials

The spectacular mud-rock floods of recent years in northern Utah have aroused widespread public interest. No doubt much of this interest has developed because many of these floods have occurred in the most densely populated part of the region where all could see their obvious destructiveness. It is not so generally appreciated that similar floods are occuring in more remote canyons in virtually all parts of the region.

Though some of these floods do not cause great immediate damage, they are, nevertheless, a serious menace because the debris carried by them will in most cases be carried into valuable reservoirs or canal systems. A study of the flood deposits at the mouth of Farmington and Bairs Canyons and of the sedimentation rate in Morris Canyon, a nonflooding tributary of Farmington Creek, sheds light on the magnitude to which sedimentation rates in this region can be increased by such floods.

During the past 11 years the 167-acre Morris Canyon has yielded a total of 2 cubic yards of sediment. This is equivalent to an average annual sedimentation rate of 0.0004 acre foot per square mile.

Bairs Canyon has produced several mud-rock floods since 1912. These floods have deposited about 130 acre feet of readily recognizable sediments near the mouth of the canyon. This volume of sediment is equivalent to an annual rate during the past 35 years of approximately 1.0 acre foot per square mile of drainage area. This is about 2,500 times greater than the sedimentation rate in Morris Canyon.

Farmington Canyon produced a mud-rock flood of unprecedented violence in historic times in 1923. The deposit made by this flood and material subsequently added to it during the past 24 years, totals about 588 acre feet. This is equal to an average annual rate of 2.7 acre feet per square mile or about 6,700 times greater than that of Morris Canyon.

If the current rates of sedimentation from Bairs and Farmington Canyon had prevailed during the 10,000 years since the ancient Lake Bonneville left this area these basins would have yielded a total of 40,000 and 240,000 acre feet of sediments, respectively. In other words, near the mouth of Bairs Canyon there would be a debris deposit 40 feet deep over an area of 1,000 acres. The deposit at the mouth of Farmington Canyon would cover 2,400 acres to a depth of 100 feet. The absence of deposits of such magnitude as these clearly shows that current sedimentation rates are not normal, but represent a drastic speeding up of gradational processes.

These studies of the deposits substantiate the conclusions previously drawn from earlier geologic studies and from evidence on the watershed slopes that the recent floods and increased rates of sedimentation are definitely the result of man-caused deterioration of the plant cover and soil mantle in headwater areas. Recognition of the enormousness of the sedimentation potentials that can be released by unwise use of watershed lands should stimulate still further concern and action toward better management.

Improved infiltrometer

Three units of an improved Type F infiltrometer were developed during the first half of the year to facilitate detailed studies of watershed protection requirements. The successful performance of these units in exploratory test runs later in the year suggests that a number of the features incorporated in the apparatus may be found useful in other regions.

The new units were designed to measure overland flow and soil losses caused by simulated rainfall of controlled intensities on 6 x 6-foot plots by a 2-man crew. Most of the apparatus was constructed of aluminum. These gross features effected about a 50 percent economy in the water, transportation, and manpower requirements of the standard Type F unit.

A number of functional improvements were also included in the new design. Nozzles are set in individual, adjustable, shower head receptacles which, through slight changes in nozzle tilt, make possible a highly uniform application of rainfall on the plot. Water is fed to nozzles by individual hose lines from a large surge tank. Each nozzle line is equipped with a valve at the surge tank. These valves make possible rapid changes in the number of operating nozzles and the simulation of any desired rate of rainfall between intensities of about 1.50 to 7.00 inches per hour. Two trough-type rain collectors connected to a tipping bucket-photo electric cell-veeder counter-device provides a record of rainfall by 0.005 inch increments. The collection of 5- to 10-second samples of runoff and subsequent filtering and weighing were found to be the most simple methods of determining runoff and soil losses.

Protection requirements of granitic soils

In resuming studies at the Boise Research Center, inspection and consultation with forest officers revealed that several erosion control problems continue to exist in the Boise River watershed. Notwithstanding substantial relief from grazing, extensive areas of grassland spring-fall range at the lower elevations are continuing to erode. Large grass fires have aggravated the situation. Reseeding of burns has been fairly successful on the best sites but even on these areas the amount of grazing that should be permitted is not known. In the Stipa-Lupine summer range areas at high elevations, soil is still being lost for lack of accurate criteria of protection requirements. Roads continue to be a problem. To these problems of long standing has been added a new menace brought on by an expansion of logging operations in ponderosa pine which are now stirring the soil on 13,000 acres per year with uncertain prospects of restabilizing the mantle.

As a start toward the detailed study of these problems, infiltrometer tests were made within the Woodtick enclosure near Arrowrock substation last summer for the dual purpose of testing the new apparatus and of learning which of the observable site characteristics--of plant cover and soil--are most indicative of runoff and erosion behavior. All plots were subjected to 1.80 inches of rain at a constant rate of about 3.60 inches per hour to simulate the occurrence of a major summer storm. The data have not yet been completely analyzed but inspection of the material indicates several outstanding relationships.

Surface runoff ranged from 0.85 to 38.0 percent and soil losses ranged from 104 to 3,088 pounds per acre. The extent to which the ground surface was covered by basal area of plants and litter appears to be the most significant single index of runoff. Removal of the herbage apparently had no material effect on runoff. Least runoff occurred on deep soil, and on sites with the greatest pore space.

Ground surface coverage was also the best single index of erosion, though the correlation is not nearly as perfect as with runoff. Much of the variation in erosion appears to be due to the effect of above ground herbage density and to the depth of the soil. These secondary relationships are believed to be due in part to the effect of above ground herbage in breaking the impact of raindrops and to the effect of slope.

This exploratory study substantiates the results of previous studies with respect to the dominant influence of the plant and litter cover on the surface of the ground. It also shows that soil profile characteristics as well as slope steepness must be included in criteria for determining watershed protection requirements.

Protection requirements of limestone soils

An infiltrometer study was initiated last summer on the 10 acre area A and B experimental watersheds at the Great Basin station to determine the factors responsible for the runoff and erosion behavior of herbaceous range on limestone soil. Time permitted the making of only a small number of exploratory tests but these tend to verify a growing volume of evidence regarding the protection requirements for subalpine herbaceous range.

Ten sites on area B were subjected to 1.50 inches of rainfall at a rate of about 6.00 inches per hour. The soils on these sites varied widely with respect to depth, erosion pavement and slope but all had very little plant or litter cover on the surface (10-40 percent) by reason of very heavy overgrazing to which the area has been subjected in the past two years. All of the plots yielded about 90 percent runoff. Soil losses ranged from 1,000 to 9,000 grams per plot (or 2,600 to 23,400 pounds per acre) the most significant factor affecting this variation being slope steepness. These high runoff and soil loss values are not surprising in that they are comparable to those obtained in other infiltrometer tests on poorly covered sites. They also explain why runoff and erosion from area B has increased during recent years after having been closely grazed and heavily trampled by sheep.

Time permitted only four tests on area A. Two of the sites tested were about as bare as those on area B and yielded comparable amounts of runoff and eroded material. A site with a 61 percent ground cover yielded 21 percent runoff and 180 pounds of eroded soil per acre and a site with 88 percent ground cover yielded 9 percent runoff and about 205 pounds of soil per acre.

The high runoff and great soil losses from the poorly covered sites tested in area A explain why this area continues to lose soil in spite of the generally improved condition of the watershed as a whole. These measurements also emphasize the necessity for achieving adequate control of runoff and erosion on all sites, including areas of less than an acre in extent. It is not yet certain whether a 200-pound per acre soil loss during a major storm is a safe minimum for watershed protection purposes. Further tests are needed to determine this requirement and the criteria by which to judge when satisfactory watershed conditions are achieved.

Plans for 1948

At the Wasatch Branch: (a) complete analysis and publish results of summer storm and flood deposit studies; and (b) develop from accumulated records a report on watershed protection requirements for the woodland, brush and herbaceous cover types typical of the Wasatch Front.

At the Boise Branch: (a) complete analysis and publish a report on the 1947 infiltrometer study and prepare descriptive report on the improved infiltrometer; and (b) initiate a detailed study of the watershed protection requirements of grassland spring-fall range and Stipa-Lupine summer range.

At the Great Basin: (a) complete publication of flood potential article; (b) continue infiltrometer study of watershed protection requirements; and (c) continue analysis of A-B data.

Influence of Forest and Range Cover on Stream Flow

It is typical for streams in this region to rise rather gradually in the spring and attain moderately high discharges which are sustained for several weeks and to subside gradually to a low stage of flow during the summer, fall, and winter months. Exceptionally deep snow and rapid melting occasionally cause destructive floods, particularly on such major streams as the Boise and the Weber Rivers. The most violent and destructive floods in this region, however, are the debris-flows which occur in steep, minor tributaries during high intensity summer rains. All parts of the region are subject to this type of flood, but the hazard is especially great in northern Utah.

Summer flood control

Research at the Wasatch Branch has produced conclusive proof that mud-rock floods can be induced by deterioration of the plant cover and soil mantle on less than 10 percent of a drainage basin. It has also produced a solution to the prevention of such floods. This solution in simple terms involves the restoration of the original capacity of deteriorated areas to infiltrate and store rainfall through the construction of contour trenches, provision of artificial reseeding, and protection from fire and overgrazing. Last year a Departmental publication was prepared on the results of this research as a guide for the solution of similar flood problems elsewhere.

Further flooding in drainage basins adjacent to the experimental watersheds at the Wasatch Branch last summer focused attention on the need for accurate designing and maintenance of the countour-trench system of flood control. On August 10, 1947, a rain of about 1.00 inch magnitude with intensities ranging up to nearly 8.50 inches per hour for the maximum 5-minute period caused mud-rock floods from three small tributaries of Farmington Creek (Halfway, Whipple, and Corduroy) and from Bairs Creek, the headwaters of which lie immediately north of the north rim of Farmington Canyon. Some contour trenching and reseeding had been done in all of these basins toward the end of the CCC program in 1937 and 1938. The trenches constructed here were fewer and smaller than those installed on the experimental areas in Parrish, Barnard, Davis, Ford, and Steed Canyons. These lower standards of construction were used on the assumption that natural revegetation would be sufficiently rapid for achieving effective control on untrenched areas.

Examination of the ruins left by the floods revealed numerous weaknesses in the design of the control works. Because inadequate provision had been made for handling drainage from the work-access road, sufficient runoff accumulated to rip out and drain large segments of the trenched areas, thus permitting a rapid concentration of runoff in the headwater channels. Failure of reseeding and natural revegetation on both trenched and untrenched areas in many places produced enough runoff to cause additional trench failure and thus to augment the flow in natural channels. It was also evident that a considerable volume of trench capacity had been lost prior to the storm due to erosion on inter-trench areas where plant cover had failed to develop as expected.

These observations point up the need for greater care in designing flood prevention measures. For one thing, much less reliance should be placed on achieving quick and adequate recovery by either artificial or natural revegetation on seriously deteriorated sites. It is evident that deterioration will continue on such sites for many years even though given complete protection from fire or grazing. Because of the slowness of recovery on deteriorated sites it becomes essential that contour trenches be constructed with sufficient capacity to hold the maximum problem runoff and that provision be made for maintaining this capacity until effective vegetational control has been established. It is also clear that road construction must include adequate provision for the safe handling of drainage.

Stream flow records

During the past year all of the streamgaging stations at the Great Basin Branch were cleaned and repaired. Revised rating curves were developed from current meter readings. Stream flow discharges were calculated for the Ephraim Power Plant, East Portal Ephraim Tunnel, Dave Madsen Ditch, and John August Ditch covering the period 1940-47. Plans were also drawn for improving the area A and B gaging stations so as to obtain detailed unit storm records.

Plans for 1948

Publish report on the Bairs Creek flood. Continue stream gaging records on experimental waters at Wasatch and Great Basin Branches.

Water Utilization

The naturally low flow of streams during the summer and fall months is the most critical factor limiting the economic development of this region. Reservoirs for storing surplus winter and spring runoff have been the principal means of conserving water for use in the summer months. Some additional reservoir projects are feasible, particularly on the larger rivers such as the Snake and the Colorado, but these are very costly and will not satisfy for long the growing demands for more and more water. The time has already arrived in many localities and is not far off in others for developing additional water supplies by making reductions in the consumptive losses of water, including those losses which occur by evapo-transpiration on watershed lands.

Aspen harvesting

Results of an exploratory soil moisture study at the Wasatch Branch last year suggest that the harvesting of aspen may be a means of increasing the useful yield of water from mountain lands. In this study the amount of water in 6 feet of mantle was determined at weekly intervals through the growing season on a denuded aspen site, a site on which aspen had been removed without disturbing the herbaceous cover and litter, and on an untreated aspen site. Precipitation at the ground surface was also measured.

Thus far, calculations of soil moisture have been completed for a few weeks at the start of the growing season and for the end of the season. By subtracting the total amount of mantle moisture at the end of the season from that at the start and adding summer precipitation, evapo-transpiration losses were found to be as follows: 20 inches from untreated aspen, 15 inches with aspen harvested, and 7.5 inches from a completely denuded site.

The 12.5-inch lower water loss from the denuded site than the aspen site suggests on the face of it that complete denudation would materially increase water yields. However, such a course is unthinkable because denudation immediately creates a flood hazard. A runoff plot which had previously lost no measurable amount of soil over a period of 12 years, in the first year of denudation lost about 142 cubic feet of soil per acre in one storm.

The 5-inch lower water loss from the harvested aspen plot than from the untreated plot, however, suggests that removal of aspen without injuring the understory and litter may be highly beneficial in several respects. One possibility is a yield of 5 more inches of water from the harvested site, with no loss of soil stability. Others include a useful crop of aspen for excelsior, pulp, etc., and greater forage production. Such benefits as these are as yet speculative. The importance of the benefits suggested by these first-year records, however, justifies a continuation of the study.

Bunchgrass cover

Restoration of perennial bunchgrasses has long been recognized as a requirement for stabilizing eroding granitic soil on the Boise River watershed, but questions have been raised as to whether this type of cover may not utilize excessive quantities of water and thereby decrease water yields. Studies of soil moisture on reseeded range and poorly covered range a number of years ago showed that both sites became about equally dry by the end of the season, indicating no greater loss from the densely covered stable site than the poorly covered eroding site. However, volume weight measurements were not made so as to permit accurate conversion of these values into inches of water.

Last year volume weight determinations were made on the original study sites. Recalculation of the soil water values for one year of records during which soil moisture was sampled to a depth of only 30 inches shows that evapo-transpiration losses were 6.45 inches on the densely covered bunchgrass site and 6.31 inches on the annual weed site--a difference of 0.14 inch. Recalculation of the records taken during the next year when moisture was measured to a depth of 6 feet, shows that the bunchgrass site lost .45 inch less water than the annual weed site--the actual losses being 15.78 and 16.27 inches, respectively. These results not only substantiate the tentative conclusions drawn from the earlier soil moisture study but indicate that a vigorous crested wheatgrass cover utilizes less water than a sparse cover of annual weeds.

Plans for 1948

a. Continue the aspen water utilization study at the Wasatch Branch, adding Coleman moisture meters to the instrumentation, if available.

b. Complete analysis and publish report on the Boise bunchgrass water utilization study.

Climatic Effects of Forest and Range Cover

The great bulk of the useful stream flow in this region is derived from snow that accumulates on the high elevations to great depths during the winter months and that melts in the spring. Interception of snow by vegetation and its evaporation during the accumulation period decreases the amount of precipitation that reaches the ground as potential stream flow. Also, rapid snow melting results in high spring discharges which may reach flood proportions and a subsequent early recession to low stages of stream flow. Any watershed treatment which will decrease the interception-evaporation loss and at the same time prolong the melting of snow will therefore tend to sustain stream flow into the summer months when water is most needed.

Great Basin snow studies

Snow studies conducted at the Great Basin station several years ago revealed that full shade reduced snow melting rates by about 50 percent of the rate of melting on sites with full insolation. Last winter further exploratory studies were made to determine whether such reductions might be effected through the manipulation of forest cover, and also to investigate the possibilities of increasing the accumulation of snow.

These studies revealed that aspen cover has little effect on either snow accumulation or rate of snowmelt. Aspen sites do have a high evapo-transpiration loss in the summer months, however, as was found at the Wasatch Branch so that aspen harvesting may be beneficial from a water yield standpoint in spite of not affecting snow accumulation or melting.

Open stands of white fir also appeared to have but little influence on snow accumulation and melting as compared to nontimbered sites. In more dense stands of spruce, however, there was evidence of considerable interception loss and a one-third slower rate of melting than on open sites. These observations are in substantial agreement with results of more detailed studies made at Frazer, Colorado and suggest that the creation of openings in dense spruce may be beneficial from a water supply standpoint.

In these exploratory studies it was found that individual trees and clumps of trees as well as ridges were effective in the formation of drifts. These drifts contained from two to several times the water content of the undrifted mantle and remained from one to many weeks after snow was gone on undrifted areas. If more drifting could be induced by creation of tree wind breaks or by snow fences, the prolonged melting of such drifts should further delay the recession of stream flow.

Plans for 1948

Continue snow accumulation and melting studies at Great Basin.

Start analysis of accumulated records on snow accumulation and melting developed from studies in ponderosa pine at Boise Branch.

RANGE MANAGEMENT RESEARCH

The objective of range management is to graze the range in such a way as to get most out of it, in terms of beef and mutton, without damage to the range itself or sacrifice of other values. Management attempts to maintain or improve the amount and quality of forage. To do this effectively the manager needs to know potentialities of the range (which are often little realized on range in run-down condition), how these potentialities may be achieved, value of various plant species as forage, how the most valuable species may be encouraged, and effects of other factors--such as weather--on the range which might be confused with effects of grazing. To provide answers to these and similar questions is the job of range management research.

But the management job--and the research job--is complicated by other questions than production of forage and livestock. Range vegetation has a soil protective function which is usually damaged by improper grazing; and protection of the soil is important not only to perpetuate a supply of forage, but to perpetuate other values. Moreover, grazing by livestock may conflict directly with other values, such as timber or wildlife. In cases of conflict, the management job is one of reconciling and balancing uses, but in the case of soil protection no compromise is possible, for preservation of the soil is fundamental to all uses.

Despite these complications, management of grazing lands rests upon two simple, basic facts. These are: first, that vegetation serves to check soil erosion, and second, that vegetation can be changed by grazing use.

The amount of change that vegetation undergoes as a result of grazing is not generally appreciated. Research has brought to light astonishing changes in the character of range vegetation since settlement in many parts of the West. Similarly, the effectiveness of vegetation in preventing erosion and floods is greatly underestimated by the public at large. The effectiveness of low-growing herbaceous cover is particularly liable to slight, perhaps because the individual plants are not of impressive size. Yet, when all the facts are in, and the reciprocal development of vegetation and soil over the ages is properly appreciated, it is found that even lowly herbs and grasses may be as effective as lordly forest trees in stabilizing the soil.

The problem of siltation from grazing land is a problem of insufficient vegetal cover. Because of widespread abuse and denudation of native vegetation, restoration of an effective cover for preventing erosion is the most urgent problem facing management. Tied in with this problem is one of increasing the abundance of high-value plants at the expense of inferior and undesirable species, and thus increase the grazing capacity of the range. Finally, it is the concern of management, having once improved a piece of range, to maintain the advantage that has been gained.

Soil instability is not restricted to any one class of wild land. On the desert, under conditions of high aridity and sparse vegetal cover, natural erosion is rapid and little soil development occurs. One might suppose that destruction of desert vegetation would not make much difference, but the fact is that destruction of even this sparse vegetation intensifies erosion greatly. At the other extreme, on high mountain grazing land, a humid climate promotes dense vegetal cover and a deep mantle of soil usually forms, representing centuries of slow, constructive development. When the vegetal cover is greatly reduced, erosion is very rapid because of the prevailing steepness of slope. Floods, their dramatic quality intensified by the nearness of human settlements in the valley below, may occur.

Between extremes of arid desert and humid mountain grassland are all intermediate conditions of natural moisture supply and corresponding density of vegetal cover. In each case the fundamental cause of siltation is a lessening of vegetal cover on rangelands, usually by overgrazing. While this statement is true of all situations, specific management problems require specific measures because of the tremendous variation in the character of western rangelands.

The problem of range-management research, while directed at the question "How should these lands be grazed?" is actually one of understanding range vegetation. We have come to realize that in order to understand vegetation we have to understand it in relation to its environment. First and foremost, we have to understand the soil, both for its own sake (since soil stability is the prime objective in management), and because it, like the undisturbed and natural vegetation, is a key to understanding the entire range complex. In addition to vegetation and soil, we have to understand the other factors in the complex--climatic, topographic, and biotic. The research problem, therefore, is ecological in character.

Summer Range

During the past year, an ecological study on the Wasatch Plateau was brought to practical completion. A bulky manuscript, "Subalpine Vegetation of the Wasatch Plateau, Utah" was prepared embodying the results of research and plot records extending over the past 35 years. This manuscript is now in process of revision. Some field work of an observational nature remains to be done in order to clarify certain phases of natural succession. Part of the coming summer will be spent on this work and in revising the manuscript for publication.

The purpose of this study has been to reconstruct the character of the original vegetation in the subalpine zone, which has been greatly modified since settlement, and to describe the changes that vegetation has undergone, primarily as a result of grazing by livestock.

The evidence of change used has been gained in part by field observation during the past 10 years. This has included observation of trends currently taking place (as may be inferred by age classes of various species), comparison of range under different kinds of grazing use, study of natural areas and of relic species, observation on forage preferences of sheep and cattle, and study of the phenological development of plants. Aerial photographs have been used with profit. An important part of the evidence of change is based upon permanent plots and quadrats established as far back as 1913, on separate range surveys made by the Manti National Forest in 1912-14 and in 1936-38, and on old photographs, a few of which date back to 1910. In short, a wealth of basic data and opportunities for observation have been combined into a detailed ecological report which modifies the results of an earlier study by A. W. Sampson (Plant Succession in Relation to Range Management, USDA Bul. No. 791, 76 pp, 1919), besides being considerably wider in scope than this earlier publication. Highlights of this report are summarized below.

Plant communities

The most important plant community of the subalpine zone is the mixed upland-herb association. Its importance derives from the facts that it is more extensive than any other and that it is the focus of a conflict in use. As watershed cover this community is most vulnerable to abuse by overgrazing. Most of the accelerated erosion observed today occurs in it, and it is the chief source of torrential summer floods. The chief variations within the upland-herb association are grouped as follows:

1. Herb-dominated communities on cattle range
2. Grass-dominated communities on sheep range
3. Low shrub communities
4. Communities of ephemeral species
5. Erosion-pavement communities

In addition to the mixed upland-herb association, six distinctive communities are recognized. Two of these are dominated by trees, one by shrubs, and three by herbs and grasses. These communities are, in order of areal extent: spruce-fir association, tall shrub communities, wet meadow communities, limber-pine consociation, tall-herb association, and alpine relic association.

Because of its importance, and because all the old permanent study plots have been located in it, most attention has been given to the mixed upland-herb association. A knowledge of the original character of this mixed upland-herb association is of the utmost importance to range and watershed management. The practical range manager needs this knowledge as a basis for determining objectives in management.

Mixed upland-herb association

Various lines of evidence--natural areas, relic herbs and grasses in the shelter of shrubs, range under different degrees of use, and permanent plot records of trends in secondary succession, all indicate an original vegetation of more mesophytic character than prevails today. Although it has been widely believed that the original, undisturbed vegetation was dominated by a single species over extensive areas, these various lines of evidence point toward an original upland-herb association that was a mixture of many species of tall, succulent herbs, grasses, and sedges. The following species were probably among the most prominent:

Mertensia leonardi
Agropyron trachycaulum
Valeriana occidentalis
Osmorhiza occidentalis
Heracleum lanatum
Angelica lyallii
Polemonium foliosissimum
Erigeron speciosus
Bromus carinatus
B. anomalus
Carex festivella
C. hoodii
C. raynoldsii
Aquilegia coerulea
Castilleja sulphurea
C. leonardi

The cover density of vegetation and litter was undoubtedly well in excess of 50 percent, and probably was on the order of 70 percent even in rather dry situations. Vegetation and litter formed a cover that was uniformly dispersed, with bare spaces small and scattered, in contrast to patchy vegetation that occurs in many places today, with bare eroding soil between patches. Observable erosion of the surface soil was practically absent throughout the entire community.

The details of primary succession cannot be worked out for all sites, because of modifications in vegetation and soil that have been produced throughout practically all the subalpine zone by overgrazing. However, in the roughest, most inaccessible parts of the subalpine zone, on and adjacent to limestone talus slopes, a sufficient series of undisturbed areas can be observed to give a rough outline of the essential character of primary change in vegetation and soil.

The initial stage is one of tumbled talus rock with very little vegetation, and almost no soil, in evidence. Lichens are not sufficiently abundant to exert much influence in forming soil.

Physical weathering of the limestone appears to be very much more important. Pioneer species of vascular plants are of two sorts. Trees, chiefly spruce and fir, and some shrubs, invade crevices and become established in the talus. In the early stages these woody plants are widely scattered. Individuals may or may not reach an advanced age, depending on how greatly the limestone cliff has retreated which gives rise to the talus. In time talus becomes essentially stable, and, the tenure of trees and shrubs improving, they increase in size and number.

The other class of pioneer plants includes a number of low herbs and several grasses that become established in little pockets of gravelly soil. (Some of these species are common on areas of accelerationed erosion pavement, an essentially similar habitat.) These herbs and grasses include *Agropyron trachycaulum*, *Trisetum spicatum*, *Poa palustris*, *Polemonium delicatum*, *Erigeron compositus*, *Anemone globosa*, and *Synthyris lanciniata*.

As soil fills in between rock crevices and increasing amounts of shrubby and herbaceous vegetation invade, the influence of the biotic factor in succession is increasingly effective. Probably at this stage chemical weathering can be considered to supersede physical weatheringin importance. The community in this stage is dominated by spruce and fir, but it has an understory of shrubs, herbs, and grasses. The soil mantle is not continuous, being interrupted by outcrops of talus rock. This stage must continue for a very long time, probably for many hundreds of years, with gradual elimination of all large rocks and eventual formation of a complete soil mantle.

With formation of a continuous soil mantle and reduction of all large rocks to soil material, the final stage in succession is reached. On north exposures dominance of spruce and fir becomes complete before all large rocks in the soil mantle are decomposed. These cool, moist sites support a conifer climax. On warm dry (south) exposures, however, trees may be eliminated rather early in succession, and tall shrubs, or mixed herbs and grasses, become dominant. With soil maturity (as judged by decomposition of rocks in the soil mantle) the mixed upland-herb association eventually dominates these warm, dry sites.

Replacement of trees and shrubs by herbaceous vegetation on southerly exposures runs contrary to commonly accepted notions of succession, but the facts point in this direction. It is quite possible, in some earlier stage of the earth's history under the influence of a cooler, moister climate than prevails today, that spruce and fir dominated the entire subalpine zone of the Wasatch Plateau. However, under prevailing climatic conditions there is no reason to think that spruce and fir can ever invade the open uplands or south-facing slopes now covered by herbaceous vegetation. The only indications of invasion of upland-herb communities by trees--limber pine and Douglasfir--are on land that has been denuded by overgrazing. On the other hand, it is quite evident that patches of timber in many places in the subalpine zone are retreating. The trees are not reproducing themselves successfully except in cool, moist sites; and on some rather dry sites where the original stand has been eliminated by logging or fire, young trees are not coming back.

Changes in the upland-herb community resulting from grazing

When the original mixed upland-herb vegetation was destroyed, by a degree of overgrazing and trampling almost inconceivably severe, the surface soil was eroded in many places, and the water table was lowered by dissection of the soil mantle with gullies. Communities of ephemeral species dominated by annual weeds (e.g., *Chenopodium album*, *Polygonum douglasii*, *Descurainia richardsonii*) and early withering perennials (e.g., *Viola nuttallii*, *Stellaria jamesiana*, *Claytonia lanceolata*) succeeded. In certain extensive areas, these have been superseded in dominance by *Madia glomerata*, an annual that was apparently introduced from lower ground and quickly gained a foothold, spreading from sheep bedgrounds. These ephemeral communities provided scant soil protection at any time, and the soil during dry summers, when the plants had withered, was particularly liable to further erosion by torrential storms.

The result was the formation, on sites of highest erosion potential, of "erosion pavement"--fragments of chert and limestone left in place after the fine particles were washed or blown away. The vegetation of these pavement areas is much like that on pockets of shallow, gravelly soil in early stages of primary succession. In some places, *Ivesia gordonii*, normally a crevice plant in alpine situations, has spread following loss of the soil mantle. Except for the exposure of bedrock in certain places (which are much less extensive than these areas of erosion pavement) erosion pavement areas represent the most extreme deterioration in the subalpine zone. Continued grazing and trampling by livestock keeps them from becoming stabilized; indeed, it is by no means certain that they would become stabilized in a reasonable time without artificial restorative measures in addition to the exclusion of livestock.

On sites where the original soil mantle was deeper or the natural erosion potential less, communities of ephemeral species have been invaded by certain perennials. On sheep range the invading species have been preponderantly grasses (*Stipa lettermani*, *Agropyron trachycaulum*, *Trisetum spicatum*, *Bromus carinatus*), although *Taraxacum officinale* and the rhizomatous herbs *Achillea lanulosa*, *Artemisia discolor*, and perhaps *Penstemon rydbergii*, have also invaded strongly. In contrast, on range grazed by cattle, grasses have generally been suppressed, and the chief invaders have been *Geranium richardsonii*, *Taraxacum*, and the rhizomatous species, *Artemisia*, *Penstemon*, *Aster chilensis*, and *Erigeron ursinus*.

Three species of low shrubs have also invaded these uplands aggressively in recent years. These are *Chrysothamnus viscidiflorus*, *Artemisia rothrockii*, and (at the northern, lower end of the Plateau), *A. tridentata*. These low shrubs are not likely to be soon superseded by herbaceous vegetation, even if all grazing were to be excluded, for they are long-lived.

When intensity of grazing is lessened, tall herbs (and certain grasses and sedges) tend to increase in grass-dominated communities on sheep ranges, and tall grasses and sedges (and certain herbs) tend to increase in herb-dominated communities on cattle range, a trend toward restoration of the original, mesic, mixed upland-herb vegetation. The restoration cannot be complete during the lifetime of any persons now living, however, because of the soil losses that have occurred and that are still occurring. Nor will the original vegetation ever be precisely restored, because of the probable persistence of introduced species. It is possible, too, that certain species present in the original vegetation have been completely exterminated in the subalpine zone of the Wasatch Plateau.

Among species that records show to have increased markedly in the subalpine zone since domestic livestock began to graze the Plateau, and that still appear to be increasing, are:

Taraxacum officinale
Chrysothamnus viscidiflorus
Artemisia rothrockii
A. tridentata
Artemisia discolor
Helenium hoopesii
Madai glomerata
Penstemon rydbergii

Some of these species have been introduced to the subalpine zone since the white man's occupation of Utah. Annual weeds, Polygonum douglasii, Chenopodium album, Descurainia richardsonii, Lepidium densiflorum, et al., (species also probably introduced) were very abundant until about 30 years ago. Since then they have diminished generally, tending to be replaced either by another introduced annual, Madia glomerata, or by perennial herbs and grasses. The rhizomatous herb, Achillea lanulosa, reached a peak in dominance about 20 years ago, and has since diminished greatly in dominance throughout most of the subalpine zone, whereas other rhizomatous species (Artemisia discolor, Penstemon rydbergii) which have been increasing steadily for many years, tend to maintain their dominance, especially under heavy grazing. These, and other rhizomatous herbs, facilitate the invasion of herbs and grasses that reproduce only by seed, evidently by modifying microclimate and stabilizing soil of formerly denuded surfaces.

In addition to specific facts brought out by this study concerning character of original vegetation and trends under grazing, it is concluded that heavy grazing exerts a profound influence on the site itself. By reducing cover and exposing soil, heavy grazing changes a mesic to a xeric environment. This effect is intensified by accelerated erosion. The changed character of environment is reflected in losses of mesic species and increases of xeric ones. Trends in vegetation under grazing, therefore, are not only influenced by forage preferences of the animals and by morphology, phenology, and reproductive powers of the plants, but also by the degree to which the environment is made drier by grazing and trampling.

Comparison with earlier ecological study

In comparing the results of the earlier study by Sampson with those of the present study, it will be seen that they agree in some particulars but differ in several important respects. The chief points of similarity are:

1. . Both studies recognize that the community of ephemeral species is a primitive stage in succession. (This "first weed stage" or "early second weed stage," in secondary succession was mistakenly identified with primary succession in the earlier study.)

2. Both studies recognize that the community of ephemeral species may be succeeded by rhizomatous broadleaved herbs (Achillea lanulosa, Artemisia discolor, Penstemon rydbergii), and that these rhizomatous patches of vegetation may be invaded by grasses.

The chief points of difference are:

1. While the earlier study concluded that the climax herbaceous cover was a community dominated by wheatgrasses, the present study concludes that the original vegetation was a mixture of mesic herbs, grasses, and sedges. It is concluded, too, that this herbaceous vegetation is not succeeded by a timber climax, as was assumed in the earlier study.

2. In considering secondary successional change from dominance by ephemeral species to a wheatgrass subclimax, the earlier study considered communities dominated by perennial broadleaved herbs and by Chrysothamnus and Stipa, to represent progressive intermediate steps. The present study, in contrast, considers these (and also extensive wheatgrass-dominated communities) to be essentially equivalent in successional rank, the product of different grazing pressures, difference sources of seed, and different degrees of soil stability. Grasses, as well as broadleaved herbs, readily invade ephemeral communities under certain circumstances; moreover, Chrysothamnus appears able to maintain itself a long time and is not readily killed out by wheatgrasses.

3. The earlier study identified the successional phases induced by overgrazing with normal vegetal succession and concurrent soil development. It considered "retrogressive" succession (involving destruction of vegetation and soil) to be the converse of "progressive" (i.e., normal, primary) succession. The present study regards these two kinds of change as fundamentally different in character. Accelerated soil erosion is not the opposite of normal soil development, nor is secondary succession resulting from denudation by overgrazing the same thing as primary vegetal succession. It is the same only when most of the soil is destroyed and primary succession must begin again, either upon bare bedrock or erosion-pavement gravel.

4. Considering the motivating factors in secondary succession, both studies agree on the importance of soil organic-matter content; yet the earlier study considers it more nearly limiting than the present one does. In the earlier study other principal motivating

factors are considered to be depth of soil-moisture penetration under different kinds of cover (penetration being assumed to become less and less as vegetal cover becomes increasingly dense), and differences in root length of the various perennial species. In the present study, in contrast, the principal factors motivating secondary succession are considered to be availability of seed, forage preferences of grazing animals, soil stability, and the character of microclimate. Moisture penetration is obviously a factor, but in the opposite sense to that indicated in the earlier study, in effective storms being deeper under a dense than under a sparse cover.

The problem of revegetating denuded mountain slopes

Numerous applications may be made of this basic study, for it relates to one phase of management or another on many subalpine range-watersheds of the West. One immediate application is a keener appreciation of the problems we face in attempting to stabilize the soil of eroding mountain slopes. These slopes have been eroding with abnormal rapidity for many years. The original cause of their present condition was denudation by overgrazing. The seriousness of this erosion, the full extent of its abnormality, has never been widely realized, and this is one reason these slopes have continued to erode at accelerated rates during the period they have been under national-forest management.

A clear distinction between the changes undergone by soil and vegetation in normal succession, as compared with the changes they undergo following denudation by overgrazing, enables us to face this problem realistically. Obviously denuded slopes which support nothing more than a cover of annual weeds are not a "first stage in succession" in the sense that a raw talus slope is a first stage. Successional change on such denuded soil is radically different from successional change on a talus slope. It is different not only because the species of plants are different but even more fundamentally because vegetation and soil are no longer in harmony with the rest of the environment. On the talus slope, once the fall of rocks ceases, vegetation and soil are in harmony with their environment. In other words, rather than a measure of stability which permits a building up of soil and vegetation, we have on the denuded area a continuing attrition of the soil, and destructive rather than constructive processes in operation.

With this fact in mind, it will be appreciated that widespread exposure of a subsoil is something new under the sun. Nature, in our time at least, has never produced conditions of this sort on a wide scale. It cannot be assumed that more removal of livestock from severely eroded slopes "will allow nature to take its course" and eventually solve the problem. The course that nature takes in such circumstances may effect a cure in the next millenium rather than in this, and may require complete destruction before constructive processes can gain ascendancy.

(2) This positive correlation between size of plant and degree of utilization is not so pronounced for early season utilization as it is for late season utilization.

(3) Average utilizations of the two species are about as follows:

	Early	Late
Mountain brome	35	85
Slender wheatgrass	7	55

Whereas we would expect light use to be more selective, the increasing degree of positive correlation between plant size and intensity of utilization as the season advances means that late season, heavier use is actually the more selective. This fact may be related to seasonal development of flower stalks.

(4) A given degree of utilization on a certain plant tends to be followed by a similar degree of utilization next year. This, taken with the conclusion that size of plant is inversely correlated with degree of utilization, means that once plants reach large size, they are little used year after year.

(5) Weight changes or growth of plants, as determined from estimates of weight of individual plants in two consecutive seasons before grazing started, seem to be affected by both time and intensity of utilization. "Heavy" utilization early in the growing season tends to be followed by greater weight gains than follow early "light" utilization. In contrast, heavy utilization late in the growing season tends to be followed by smaller weight gains than follow late light utilization.

(6) Light late utilization is followed by lower plant mortality than follows heavy utilization. The significance of this fact to the plant community is unknown.

(7) On these short (<80 feet) and mostly gentle (<50 percent) slopes there is no evident relationship between degree of utilization and distance up or down the slope.

To see if grazing was influenced by the other plants a given grass plant grew with, estimates were made of weights of the various species growing within 2.83 ft. of the point where the staked plants occurred. Area of these plots was 25 square feet. These conclusions followed on sheep grazed range:

(8) The more weight of grass occurs on a plot, the less is the percentage late utilization of wheatgrass.

(9) The more weight of dandelion occurs on a plot, the less is percent utilization of both grasses.

Generalized utilization estimates for the area suggest two different reasons for the relationships found: (1) Sheep avoid grazing wheatgrass altogether. (2) Sheep prefer dandelions to grass where both occur on the same area.

The aspen condition study was undertaken to assess condition of the type in relation to its potential condition. It marks a shift in emphasis by the project from study of individual plants to study of plant communities. This shift has been necessitated by inability to use fully data from studies of the utilization, physiology, and responses of individual plants. The plant mortality data considered as item (6) above are a case in point. The individual plant approach has led to studies of proper use, carbohydrate metabolism, volume-weight relationships, and finally Plant Vigor and Site. The plant community approach has yielded modifications of proper use factors for individual species depending on what community that species grew in, stages of plant succession as indicators of condition, and recent work on condition and trend. Underlying the latter type of investigation has been the concept that the plant community develops in harmony with normal plant and soil successions leading to climax communities.

The aspen condition study has covered in a reconnaissance fashion some aspen stands in Utah and southeastern Idaho. More intensive records including quantitative data on herbage production, aspen tree site indices, site factors, and plant and litter cover were taken during parts of the last two summers in 33 stands on plots of 1,000 square meter size.

We have concluded the aspen type is tremendously variable. Its appearance of homogeneity is superficial. On all our 33 plots only one species is constantly present--aspen itself. Some of this variation in species composition is due to natural differences in plant ranges. Part is obviously due to different rates, and stages, in the normal succession of aspen to various types of coniferous forests. Not only the overstory trees succeed one another; so do the understory shrubby and herbaceous plants. Man has modified these normal successions by burning, cutting, and, most importantly, by grazing either of domestic stock or game at intensities far above normal. Also, aspen occurs on sites which are various in relation to climate. Finally, actual composition of the aspen stands is related also to other vegetation types with which the aspen stands are in contact. For example, near the lodgepole-Calamagrostis stands at the north of our area are found aspen-Calamagrostis stands. The clover common under spruce at the south of our area is there also common under aspen. Thus, use of indicator species throughout the aspen type is difficult.

However, in the absence of extreme values of the conditioning factors climate, soil, topography, biota, or time, and especially and particularly in the absence of concentrated livestock or game use, we have evidence that the natural aspen understory contains much

Mertensia leonardi
M. ciliata
Senecio serra
Heracleum lanatum
Osmorrhiza occidentalis
Hackelia floribunda
Valeriana occidentalis
Elymus glaucus
Poa reflexa
Symphoricarpos spp.
Pachistima myrsinites
Amelanchier spp.
Rosa spp.

Only *Symphoricarpos* of all the shrubs occupies a major role in most communities. Grasses are not abundant. This community develops not long after the catastrophe which destroyed the original coniferous forest, on fertile, gently sloping and moist but not waterlogged sites located centrally in our area. It is a mesic community. Less mesic species, most shrubs for example, occur on less mesic sites. The really drier areas, as conditioned by slope, exposure, depth of soil, etc., may never support mesic tall herbs but instead such species as *Helianthella uniflora*, *Eriogonum heracleoides*, *Thlaspi glaucum*, etc.

Grazing may confine the more moisture-loving species (e.g., *Heracleum* and *Mertensia*) to the most moist sites, as streamsides. Heavy deer use may almost eliminate the shrubs. Heavy domestic stock use eventually eliminates the more palatable tall herbs. It soon results in communities which, at best, have additions of and substitutions by *Geranium viscosissimum*, *Bromus carinatus*, and *Agropyron trachycaulum* and at worst have even fewer tall herbs and increasing amounts of such annuals as *Polygonum douglasii*, *Chenopodium album*, *Nemophila breviflora*, *Collinsia parviflora*, *Gayophytum*, and *Collomia linearis*. Grasses are not usually of major importance in even these modified stands, but they may appear abundant in the fall after weeds have dried up or been grazed. Sheep grazing tends to result in a grassy stand. Destructive use results finally in almost denuded areas with *Helenium hoopesii*, *Taraxacum officinale*, *Lepidium*, and *Cirsium*.

Grazing, then, results in more xeric communities. But these are dissimilar in species composition to communities on sites which are xeric because of natural site conditions.

Our quantitative data indicate immense variability in herbage production in the aspen, from a few hundred pounds up to a maximum of 2 tons per acre. This characteristic of aspen stands, like others such as species composition and physiognomy, is determined by the stage of natural succession to conifers, by the degree of grazing use by stock and game, by the topographic, climatic, and edaphic factors of the site, and by the availability of plant species to colonize the site. The superpositions, interactions, and reactions of all the combinations of these factors result in the characteristics of the aspen stands we have found. Our attempts at separating these variables indicate: (1) Site index of aspen shows a tendency to decrease with increasing altitude. (2) Herbage production on a given site is not consistently related to site index. (3) Overgrazing is the most important factor determining low herbage production.

The soil under well-developed aspen stands is a brown forest soil and may be described as follows:

Horizon	Depth	Color	Texture	Structure
A_0	<2 inches	Black	F & H layers progressively thinner due to rapid decomposition of the litter.	
A	<14 inches, depending on relative predominance of erosion over formation	Brown to almost black	Loamy	Granular
B	Approximately 10-20 inches deep	Light brown	Clayey	Cloddy
C	Beginning at 1-1/2 to 2-1/2 ft.	Light and inherited from parent rock	Usually mostly rock	Structureless

Aspen stands in even fair condition seem to prevent accelerated erosion. However, depth and coverage of the A_0 horizon seems directly related to pulverization and consumption of herbage by grazing animals. Depth of the A horizon is determined directly by amount of erosion.

No calcium carbonate was found in the solum of aspen stand soils except where it was inherited from a parent rock of soft muddy limestone. In contrast, free calcium carbonate formed as a result of pedogenic processes is found in the solum of vegetation types immediately adjacent to aspen--under yellow pine and low altitude sagebrush for example. It appears that at least the lower altitude, or more xeric site, aspen stands are in an ecotone between the two great groups of soils--humid and arid.

The higher altitude aspen stands, at least with increasing time, are in an ecotone between those soils where podzolization does and does not occur. Aspen stands seem able to tip the balance from podzolization. Succession to conifers tips it the other way.

Big Game-Livestock Range

Cattle and deer use range together

Preliminary studies on the Oak Creek deer-cattle range of the Fishlake National Forest show that cattle graze only 55 to 60 percent of the unit while deer graze about 94 percent. This range is rougher and steeper than many Utah cattle ranges and is heavily stocked with both deer and cattle.

Heavy use by deer occurs in some places which are inaccessible to cattle but on all areas used heavily by cattle there is also heavy use by deer. Our survey shows that while deer use much area inaccessible to cattle, in general deer and cattle prefer the same range on this unit.

Steepness of slope makes no significant difference in deer use--they graze wherever forage occurs except in very inaccessible ledges. Cattle distribution is definitely limited by steepness and roughness of slope.

Perennial grasses are severely depleted on areas readily accessible to cattle but thrive on range used by deer alone. Depletion of grass is thus attributable to cattle use rather than deer use. Curlleaf mountain-mahogany (Cercocarpus ledifolius), an abundant plant over much of the unit and a very palatable deer forage, is sharply highlined and hedged over both deer and deer-cattle range. The extent of cattle browsing on curlleaf mountainmahogany is not known for this unit but it appears that deer are largely responsible for the depletion of this shrub. Oak and some of the perennial forbs are utilized more heavily on deer-cattle range than on exclusive deer range. Thus, under present heavy stocking, these plants are evidently used by both deer and cattle.

The extent of actual conflict for forage between cattle and deer on the Oak Creek summer range is not precisely known. The foregoing data suggest that competition on this unit would be very light if cattle were stocked on the basis of proper use of grass on the accessible areas and deer were stocked on the basis of proper use of curlleaf mountainmahogany and the more palatable perennial forbs.

On other ranges in Utah exploratory studies point to direct competition between deer and cattle for certain plants. Curlleaf mountainmahogany is a preferred winter food for deer throughout the region. This shrub was heavily browsed by cattle also on parts of the Dixie and Minidoka National Forests when grass was sparse and cattle use heavy. Bitterbrush (Purshia tridentata) on parts of the Dixie, Uinta, Wasatch, and Minidoka National Forests is highly preferred by both deer and cattle. True mountain mahogany (Cercocarpus montanus) is very palatable to both deer and cattle on some ranges, and lanceleaf yellowbrush (Chrysothamnus viscidiflorus lanceolatus) is browsed considerably by deer and cattle on other areas. Clover (Trifolium spp.), an important plant on parts of the Fishlake National Forest summer range, is eaten readily by both deer and cattle. Young, tender grass is used considerably by deer on cattle range, but regrowth largely masks such use by the time cattle are permitted on the range.

Sheep and deer share forage

Preliminary studies on deer-sheep summer range on South Monroe Creek sheep allotment, Fishlake N. F., indicate that practically all species which were highly palatable to deer were also on the preferred list for sheep. These include aspen (Populus tremuloides), elderberry (Sambucus microbotrys and S. coerulea), clover Trifolium spp.), paintedcup (Castilleja spp.), and lupine (Lupinus spp.). Sheep, however, eat plants, notably grasses, which are grazed only a trace by deer in summer.

On this sheep allotment roughly 25 percent of the total area is left ungrazed by sheep. This is in fairly large blocks of rough, steep or heavily timbered country. Deer use this range and thus harvest forage which sheep cannot use. However, utilization transects show that deer prefer the same feed grounds as sheep, such as browse covered slopes, clover patches in aspen and coniferous timber, and small openings in aspen stands.

Utilization studies were made before and after sheep grazing on a spring browse range, early summer browse range, and late summer aspen range on the Fishlake and Manti National Forests. Similarities in the diets of deer and sheep on these areas are shown in percentage by forage classes in the following table:

Class of forage	Spring		Early summer		Late summer	
	Deer	Sheep	Deer	Sheep	Deer	Sheep
Grasses & sedges	22	19	24	19	3	30
Forbs	17	17	46	53	56	34
Browse	61	64	30	28	41	36

The proportions of different classes of forage in spring and early summer diets of deer and sheep are strikingly similar. Preferences for individual species within each vegetation class are also very similar. Differences in late summer diets are shown by an increase in the percentage of grass for sheep and a sharp decrease for deer. However, preferences for individual species of forbs and browse are very similar on this late summer range. It is commonly believed that competition for forage exists only on depleted ranges or on areas overstocked with game or livestock. These data, however, were collected on range in fairly good condition which was lightly used by deer and grazed moderately heavy by sheep during the period of the study. If this finding is substantiated by more extensive study it will call for a revision in the common present conception of deer-sheep food-habit relationships.

Deer summer and winter range unbalanced

Studies in cooperation with Fish and Wildlife Service and Utah State Game Deparment show that deer problem areas, as indicated by over-browsed condition of game forage, are widespread in Utah. Of the 52 major deer units in the state only 12 are without known problem areas; and 2 have recognized problem areas only on summer range. Fifteen of the 38 units with winter range problem areas also have summer problem areas. Thus on many units the summer range can support many more deer than the winter range but the reverse is true on only a few areas. A relatively small percentage of the deer range in Utah has summer and winter range equally balanced.

Problems complex--more research needed

The studies of the past year have been exploratory in nature and very limited in view of the complexity of the problems. There is evidence that big game-livestock food-habit relationships vary greatly with rate of stocking, seasonal use, type of forage, and range condition. Future work will be directed toward getting a more complete story of this phase of the big game-livestock range problem as well as attacking other phases of the problem including grazing capacity of game ranges, indicators of game range condition and utilization standards of important game forage.

Spring-Fall Range

Spring-fall sheep ranges show effects of heavy grazing

The present study of rotation grazing by sheep at the U. S. Sheep Experiment Station, Dubois, Idaho, was begun in 1941. At that time rates of stocking were set at 14, 18, and 22 sheep-days per acre in spring and similar stocking in fall, based on range in good condition. The opening of the spring grazing season was set by the date *Agropyron spicatum* reached an average leaf height of 2½ inches. During the seven years, this date has averaged April 26. Spring grazing has terminated about June 18. Fall grazing has extended from about November 20 to December 20, depending upon dates the Bureau of Animal Industry set for breeding ewes.

Four pastures make up each rotation series, thus requiring four years for complete rotation. In 1948 the last year of the second rotation, it is planned to suspend grazing treatment in 1949 to make an inventory of all pastures comparable to one made in 1940. As a preliminary, a test inventory was made in 1947 on two adjacent pastures, one heavily and one lightly stocked. The purposes of this test were to determine whether measurable differences due to grazing treatment had developed, and to gain experience in applying the weight-estimate method. Because of differences in production between 1940 and 1947, due to weather and different estimators, it appears necessary to measure trends of vegetation by the difference (1940-1947) of the differences between pastures 16a (lightly stocked) and 16b (heavily stocked). For example, the table shows the amount of *Agropyron spicatum* to have been the same in paddocks 16a and 16b in 1940. In 1947, however, heavily grazed pasture 16b produced only 55 percent as much of this important species as 16a. The change in relation between 16a and 16b, from 1940 to 1947, is 45 percent. This change may be partly due to increased production in the lightly grazed pasture and partly to decreased production in the heavily grazed pasture.

Air-dry herbage production in pounds per acre in pasture 16a (14 sheep days per acre) and pasture 16b (22 sheep days per acre) comparing 1940 and 1947

	1940			1947			% Diff.
	16a	16b	%16b/16a	16a	16b	%16b/16a	1940-1947
Agropyron dasystachyum	10.5	10.9	104	3.6	3.9	108	+4
A. spicatum	62.6	62.8	100	20.4	11.2	55	-45
Oryzopsis hymenoides	0.6	1.5	250	2.3	1.7	74	-176
Poa nevadensis	6.2	6.8	110	3.6	3.1	86	-24
P. secunda	5.3	12.8	242	7.8	6.6	85	-157
Stipa comata	9.8	14.1	144	4.0	3.4	85	-59
Total grasses	95.0	108.9	115	41.7	29.9	72	-43
Balsamorhiza sagittata	36.1	14.3	40	12.5	2.8	22	-18
Crepis acuminata	0.5	1.7	340	0.2	0.3	150	-190
Lupinus caudatus	4.8	2.9	60	8.3	0.9	11	-49
Penstemon speciosus	0.8	1.4	175	0.5	0.5	100	-75
Total herbs	42.2	20.3	48	21.5	4.5	21	-27
Amelanchier alnifolia	0.2	1.1	550	0.3	0.3	100	-450
Artemisia tripartita	239.4	161.0	67	142.6	130.2	91	+24
Chrysothamnus puberulus	25.1	25.3	101	7.3	5.8	79	-22
Gilia pungens	4.1	4.0	98	2.0	1.8	90	-8
Gutierrezia sarothrae	3.2	3.4	106	4.4	2.3	52	-54
Purshia tridentata	55.8	102.8	184	25.0	45.4	182	-2
Tetrodymia canescens	24.9	28.6	115	8.1	11.2	138	+23
Total shrubs	352.7	326.2	92	189.7	197.0	104	+12
Grand total	489.9	455.4	93	252.9	231.4	91	-2

The table shows that the important grasses in 16b declined 43 percent in relation to 16a. Most of this was caused by the change in *Agropyron spicatum*. *A. dasystachyum*, a rhizomatous species, which thrives under protection of shrubs, shows a slight increase from heavy stocking as compared with light stocking.

Herbs, of which Balsamorhiza is most abundant, also decreased from 1940 to 1947 under heavy stocking as compared to light stocking. Balsamorhiza decreased 18 percent. Other less prominent but highly palatable species decreased much more.

Shrub species have shown a relative increase of 12 percent under heavy stocking from 1940 to 1947, as compared with light stocking. This increase is due largely to sagebrush (Artemisia), and horsebrush (Tetrademia), which increased 24 and 23 percent, respectively. Rabbitbrush (Chrysothamnus), snakeweed (Gutierrezia), and bitterbrush (Purshia), all rather palatable on this range, have suffered from heavy use. Increase in sagebrush as a result of heavy stocking is taking place through invasion of areas formerly occupied by palatable herbs and grasses. Great numbers of small sagebrush plants characterize the heavily stocked range while on the lightly stocked range only occasional young sagebrush plants are found. Heavy stocking has no doubt contributed to the occurrence of the dense stands of sagebrush on many parts of the Snake River Plains.

This preliminary look at the changes taking place as a result of heavy stocking versus light stocking shows only a slight relative change in total herbage production. This indicates that as palatable herbs and grasses are depleted in early stages of range deterioration, invasion by sagebrush and other undesirables takes place, so that total herbage production changes little. The change in quality, however, is marked.

Heavy stocking shows up in sheep weights

As further evidence of range pasture deterioration, weights of ewes and lambs grazed under different rates of stocking showed significant differences at the end of the 1947 spring grazing season. The sheep used in the 1947 spring season grazed from April 18 to June 13, and in this brief period showed rather marked differences in weight changes. Lambs averaged about one week old when the animals were put in the experimental pastures

	Stocking rate		
	14 s.d. per A.	18 s.d. per A.	22 s.d. per A.
Number of ewes	31	70	56
Number of lambs	30	66	51
Av. weight change per ewe, lb.	-7.8	-10.7	-18.4
Av. fleece weight per ewe, lb.	9.7	9.7	9.7
Av. flesh weight per ewe, lb.	+1.9	- 1.0	- 8.7
Av. gain per lamb, lb.	33.6	32.0	30.8
Net gain, ewes plus lambs, lb.	35.5	31.0	22.1

The changes in total weight by the ewes involve an average fleece weight loss of 9.7 pounds; hence the changes in body weight per ewe range from a gain of 1.9 pounds on the lightly stocked pastures to a loss of 8.7 pounds on the heavily stocked pastures over this 8-week period. At the same time, the lambs gained less, by 2.8 pounds per animal, on the heavily grazed pastures as compared with the lightly grazed pastures.

Weight trends of lambs depend on the milking and mothering qualities of the ewe. The weight of the ewe depends, in part, upon the drain put upon her by the lamb. Therefore, it is logical to consider ewe and lamb together as a unit. When this is done, as in the last line of the table, the net change is seen to vary from 35.5 to 22.1 pounds, a differential of 13.4 pounds.

The failure of the ewes and lambs on heavily grazed pastures to gain weight as rapidly as on lightly grazed pastures reflects the deterioration in vegetation that has occurred on these pastures in the 7-year period 1941 to 1947.

It is not known to what extent these weight differences would persist if the animals were put on summer range with ample forage.

Winter Range

Exceptionally heavy precipitation occurred at the Desert Branch Station in the fall of 1946. In October 3.79 inches fell and in November 2.64 inches. These two months together had more precipitation than the average annual total of 6.03 inches. The result was exceptional herbage growth in 1947, particularly of shrubs and Indian ricegrass.

On heavily grazed range, growth of Russianthistle was very great in 1947. The following tabulation is from Pine Valley enclosure, built in 1937, and adjacent grazed range, showing production of air-dry herbage in pounds per acre in 1947:

	Ungrazed	Heavily grazed
Highly palatable species	550	249
Russianthistle	14	402

Palatable species, on range having had 11 years' protection, produced more than twice as much herbage as the same species on heavily grazed range. The handicap they suffer, under prevailingly heavy grazing of the open range, is evident. The annual weed, Russianthistle, on the other hand, with a low preference rating (20), was very much more abundant on heavily grazed range. The reason for this is that suppression of palatable perennials and soil disturbance in heavy grazing, together with an excess of moisture over normal, provide temporary advantage for survival and growth by this opportunist species.

Some unexpected trends have taken place in portions of the desert that have either been moderately grazed or protected altogether. Snake

Valley enclosure provides a case in point. Shortly after 1937 when this enclosure was built, marked increases of Indian ricegrass (*Orysopsis hymenoides*) and winterfat (*Eurotia lanata*) took place. These two palatable species were dominants of the protected range at the time, together with the relatively unpalatable shadscale (*Atriplex confertifolia*). Other desirable species such as black sage (*Artemisia nova*) and bud sage (*Artemisia spinescens*) also increased, but were very inconspicuous at that time.

There has been a gradual shift in dominance between palatable species on this protected range. Indian ricegrass and winterfat have tended to decline over the years. At present many of the bunches of Indian ricegrass reveal the change that has taken place. Old and large bunches are now little more than dead stubble with, in some cases, a few tufts of living grass. Many bunches are completely dead and can be kicked out of the ground. Winterfat has also tended to decline.

In contrast, bud sage and black sage have increased. Besides these shrubs a second grass, squirreltail (*Sitanion hystrix*), has increased. In 1937 and shortly thereafter black sage existed only in the shallow draws where a few stunted old bushes persisted. Gradually it has worked its way up to higher ground lying between the draws. Here, at the present time, evidence of this invasion can be detected in the form of young plants of black sage. It is clear from the existence of these age classes that black sage is increasing.

The following tabulation, giving production in pounds per acre of air-dry herbage in 1947 for some of the principal species, summarizes changes that have taken place:

	Preference rating	Ungrazed	Heavily grazed
Squirreltail	85	75	20
Black sage	75	196	23
Bud sage	75	24	7
Winterfat	70	66	33
Shadscale	30	239	319

As compared with heavily grazed range, the ungrazed range supports materially more of the palatable species. In contrast, shadscale appears to be declining under protection, a trend that would naturally be expected. Note that black sage now produces 8½ times as much herbage under protection as under heavy grazing. Its trend toward dominance is also becoming apparent: out of a total production of 685 pounds, black sage produced 196 pounds, or between a fourth and a third of the total.

But black sage can increase under moderate grazing as well as under complete protection. On part of the Desert Station in Antelope Valley the heavily grazed outside range is dominated by rabbitbrush (Chrysothamnus stenophyllus). Black sage is hedged and suppressed. Just across the fence under moderate grazing, in contrast, black sage is codominant with rabbitbrush and is reproducing aggressively.

The conclusion to be drawn from these facts is that the full course of an ecological trend is not likely to be revealed in a short time. From what was learned at the Desert Station in the years immediately following 1937, it was concluded that the better drained soils of the desert should be managed with Indian ricegrass as a major objective. At the present time we know that it is possible to manage this kind of range with black sage as a major objective. Perhaps in time, as these studies are continued, we shall have to revise management objectives again.

RANGE RESEEDING RESEARCH

Agriculture in the Mountain region is chiefly a grassland economy. Grass not only dominates the agriculture but it also gives rise, directly or indirectly, to much of the mercantile, banking, transportation, and professional activities. Income that supports schools, churches, recreation, and the high standard of life likewise has much of its origin in grass.

Social structure is also affected by the fact that it takes livestock to utilize grass, and livestock growing is essentially a rural industry. Much of the livestock graze on the range, and the ranching communities are small, comparatively far apart, and depend for summer forage on grazing on mountains, much of which is watershed land.

Since large areas of mountainous land bears plant covers that are greatly reduced and soils that are somewhat badly eroded (see watershed section), and since many of these lands recover under natural revegetation very slowly (see range management section), the reseeding of lands with damaged plant cover and disturbed soils is the most effective means of revegetating such lands. In many cases it is the only feasible method of restoring plant cover and forage.

Two-fold objective

Fortunately, the two objectives of producing forage for livestock and providing a plant cover for holding soil and preventing runoff, are in the main achieved at one operation. It is likely that a good forage cover will at the same time afford reasonable watershed protection. A thick cover of unpalatable plants might amply protect the watershed but supply little forage, The existence of such cover on some areas constitutes one phase of the need for reseeding. Generally, however, it is a deteriorated cover that causes the major difficulty, one that provides both little forage and inadequate watershed protection. This is another phase of the reseeding problem. Principal emphasis has been given to reseeding for forage production, but with an eye on watershed condition.

Large areas are in such poor condition they provide neither substantial forage production nor adequate watershed values. Reseeding in these mountainous zones therefore produces forage and contributes directly to watershed protection, whereas in the sagebrush zone it contributes forage but only indirectly to watershed protection. The great possibility of forage production on the large areas of suitable sagebrush land makes them tremendously important in protecting watersheds in that animals that have normally grazed on higher ranges in late spring and early summer may be kept longer on reseeded range and thereby lighten the grazing load on true watershed lands.

Areas for reseeding

As pointed out rather fully in last year's annual report (1946) reseeding research had progressed much further in sagebrush than in other vegetation zones, but was well under way in the mountain brush-aspen zone and was just completing the exploratory phase in the subalpine zone. The principal effort in Utah during 1947 was to prosecute research in the mountain brush-aspen zone. Work in Idaho concentrated on finishing many studies in the sagebrush zone and in strengthening the work in mountain brush-aspen zone. In Nevada, where the program was later in starting, most investigations had been in the sagebrush zone, with a beginning in the mountain brush-aspen zone. Research in the alpine zone has got under way in Utah and is barely beginning in Idaho. The largest areas suitable for reseeding are in the sagebrush zone. The areas of suitable land in the mountain brush-aspen zone are still appreciable and on the whole very productive. Tracts of range suitable for seeding in the alpine zone are comparatively small, but in most cases of "key" importance for summer grazing. Watershed values are highest in the subalpine zone although they are still high in the mountain brush-aspen zone.

RESEEDING PROGRESS IN MOUNTAIN BRUSH-ASPEN ZONE

Right now, reseeding, both research and "action" planting, is of unusual importance in the mountain brush-aspen areas. Large areas of these lands occur on the national forests, they are naturally high-producing range lands, and unless abused, the soils are very productive. They also receive higher precipitation than occurs in true sagebrush areas, but still have a growing season long enough for good grass. The subalpine zone has more precipitation but often a very short growing season. Suitable species of grass are now available for all three zones. A few examples of research findings and of areal plantings will help to make clear what may be anticipated from reseeding.

Research at Dusterberg Ridge

On Dusterberg Ridge in Ephraim Canyon at an elevation of 7,500 to 8,100 feet a native cover of mixed snowberry, serviceberry, sagebrush, and a small amount of oakbrush was removed, the area prepared for seeding, and seeded in the fall of 1944. Herbaceous understory was much deteriorated, consisting mainly of a little slender wheatgrass, needlegrass, and penstemon, Slopes varied from 5 to 40 percent. The soil was a good, deep clay loam slightly eroded in the past.

Treatments

The brush cover was removed from 45 acres by burning in late September, the seed broadcast and disked in, since drill was not immediately available; the wheatland plow was used on 50 acres and the seed broadcast ahead of the plow; on 15 acres seed was broadcast and disked; 5 acres under oakbrush and 15 acres under maple brush were broadcast without treatment; and 20 acres of sagebrush and snowberry were broadcast without treatment. The seeds consisted of a mixture of several species, found in the Majors Flat nursery to be adapted, sown at the rate of 10 to 15 pounds an acre depending on the size of seeds. On one side of the burn 15 species were sown alone except that 5 pounds per acre of smooth brome was sown on all plots.

Forage yields

Grasses on the burned area made much the most rapid growth and by August 15, 1946 had produced yields of air-dry forage of 1,500 to 3,900 pounds per acre, averaging on two transects of 20 plots each, 2,176 and 2,285 pounds per acre. Since native range was producing only about 90 to 100 pounds of forage, the burned area produced in the second year after seeding more than 20 times as much forage per acre. In 1947 the yield had increased to 2,300 to 2,700 pounds per acre or 30 times as much forage as on the open range. These yields equal more than 3 cow-months per acre.

A good stand developed during 1946 on the area treated with a wheatland plow and under maple where the fallen leaves served as a cover for the seeds. It took an extra year to give stands that are as well developed as on the burned-over area. Under oakbrush a thinner stand was still improving. Little was obtained from merely broadcasting seed, or from disking native cover after seeding.

Comparison of species

Since Majors Flat nursery is in the same ecological zone as Dusterberg Ridge, the most promising 30 species of more than 300 grown in the nursery were chosen for range tests. The well-preserved mountain soil and the estimated 26 inches of precipitation made conditions especially favorable and produced high yields. Since the site is fairly representative of considerable areas of mountainous land, the results are probably rather representative of the more favorable sites.

To determine the responses of these most promising species and to study their competitive power, smooth brome seed was distributed on the entire area at the rate of 5 pounds per acre and the species sown in strips 6 x 400 ft. and all replicated in random order. Two transects were set up by locating strips 12 feet wide and long enough to cross all species plots. One transect was fenced to prevent grazing and the other left open to observe differences in utilization. The remainder of the area was seeded to a mixture of the best species for which seed was available, using smooth brome as the base species.

The highest yielding species in green weight (dry weight is about 50 percent of green weight) are listed below. The competitive strength of these leading species is also revealed by the degree to which they reduced or were unable to reduce smooth brome from the expected 35 to 40 percent of the stand.

Table 1. Yield in green weight in pounds per acre and the percentage by weight of smooth brome grass in the stand.

Species	Yield	% Brome
Species controlling brome		
Agropyron trichophorum	8,710	7.1
Agropyron intermedium	6,715	3.2
Elymus glaucus	5,750	17.4
Agropyron repens	5,750	30.4
Bromus erectus	5,175	20.3
Agropyron subsecundum	4,850	12.4
Agropyron elongatum	4,325,	38.4
Species about equal to brome		
Agropyron cristatum	5,125	46.3
Arrhenatherum elatius	4,900	50.0
Poa ampla	4,375	57.1
Elymus triticoides	3,500	42.9
Species which smooth brome controls		
Agropyron smithii	4,965	73.8
Viguiera multiflora	4,335	74.0
Agropyron spicatum	4,315	77.6
Agropyron dasystachyum	4,315	69.5
Elymus canadensis	3,875	71.0
Medicago sativa	3,685	100.0

Forage utilization and its effects

The grass was succulent all summer and cattle congregated on the area, utilizing it heavily in 1946 and again in 1947. Moderate utilization would leave nearly 1,000 pounds of dry matter on the ground, This, in connection with the sod-forming habit of the best species should afford good soil and watershed protection. Even then the amount of feed taken would be more than 2 cow-months per acre.

Congregation of cattle on the area brought about a relaxation in grazing of the neighboring native ranges. On 400 to 600 acres of nearby range, utilization was markedly decreased, and the range showed definite increases in vigor of high-value species, and a considerable accumulation of litter on the ground. These are earmarks of range improvement. The fact that the soil was well preserved permitted natural revegetation to take place rapidly. On good sites that are protected, natural revegetation is in many cases as important as artificial revegetation.

Reseeding by Airplane

A number of seedings by airplane have been made in Utah and Idaho between 1938 and 1947. A brief summary of ground conditions and results obtained will help to clarify the status of our present knowledge. Some of these were by private stockmen, some by Federal agencies, and some were cooperative between individuals and Federal agencies. At least one seeding in Nevada was made by airplane but so far the record of it is not available. One of the Utah seedings was a carefully controlled planting made on an experimental basis. Areas seeded by airplane fall into three classes: (1) deteriorated sagebrush range, (2) mountain brush range, (3) badly deteriorated aspen range.

Summary of airplane reseeding in Intermountain Region

On sagebrush land--In 1938 one operator seeded 320 acres of deteriorated sagebrush grass range near American Falls, Idaho, by emptying from the cockpit 40 pounds of crested wheatgrass seed on each of 8 flight trips. In 1944 an uneven stand of crested wheatgrass averaged 1 plant to 50 squarefeet, between 1 and 2 percent of a stand. In the fall of 1943 a Federal agency seeded 400 acres of sagebrush-grass that had been irregularly burned, with crested wheatgrass and bulbous bluegrass at the rate of 12 pounds an acre. Flying was in strips 66 feet wide, but although a Venturi wind tunnel was used to distribute the seed, most of the seed came down in 5 to 20 feet near the middle of the swath. Heavy precipitation in the spring of 1944 produced a good stand of seedlings most of which died in the summer of 1944. Similar seeding in the fall of 1943 was made on 450 acres of thin sagebrush at the rate of 8 pounds per acre. On one part, the sagebrush was rolled down after seeding. Compared with a nearby area drilled after a burn the number of established plants were 1.5, 6, and 680 plants per 100 square feet on airplane broadcast, rolled and drilled, respectively. Near Promontory, Utah a 75,000-acre burn on sagebrush covered foothills was seeded to crested wheatgrass and smooth brome in strips about 600 feet apart. Protection from grazing for 2 years gave a good recovery of native perennial grass and about a 5 percent stand of reseeded grass in the strips seeded. Nearly all the plants of crested wheatgrass were in spots of a few square rods up to an acre where no native plants were left. Presumably, these were spots that had thick stands of sagebrush before the burn.

Mountain brush land gave better results, but either ashes or falling leaves to cover the seed was required to produce stands, except in the case of bulbous bluegrass which buries itself.

A 1,200-acre area seeded in 1943 in the foothills near Ola, Idaho showed a good distribution of seeds as caught on greased cards when seeded with 4 pounds of bulbous bluegrass per acre and 1 pound of crested wheatgrass and sweetclover combined. At first this seeded area was thought to be a failure, but bulbous bluegrass had made a good stand by 1947. Crested wheatgrass established itself in a few spots where there was some natural seed covering. A foothill range of 800 acres near Preston, Idaho was spot seeded in the fall of 1943 with 1,200 pounds of seeds of crested wheatgrass, orchardgrass, tall oatgrass, smooth brome, and timothy. Natural cover on the area seeded consisted of spots of cheatgrass and sagebrush but was largely maple brush and open aspen. In 1947 the number of established plants per 100 square feet were 0.07 in cheatgrass, 0.79 in sagebrush, and 7.1 in maple on south exposures. On northern exposures sagebrush sites had 4.2 plants per 100 square feet, maple 22.2, and aspen 55.6.

A 16,000-acre area of brush and aspen in Cow Creek drainage of the Boise National Forest was burned over during the summer of 1945. The entire area was broadcast from an airplane with 6 pounds of bulbous bluegrass seeds, 1 pound of smooth brome grass, and 1 pound of crested wheatgrass per acre. Afterwards 1,000 acres of gently sloping bottomland was drilled to 6 pounds of crested wheatgrass seeds per acre and 1 each of bulbous bluegrass and smooth brome. Areas of former brush land too rough to drill were broadcast by hand at the rate of 3 pounds of crested wheatgrass seeds per acre, 4 of bulbous bluegrass, and 1 of smooth brome. The drilled area was a great success and will in a year or two most likely produce more than 1,500 pounds of air-dry forage per acre; the hand broadcasting seems to be partly successful where ashes were moderately deep; deep ashes gave very poor results, apparently eroding badly. On the remainder of the area is a thin stand of bulbous grass that is variable in distribution. One more year, perhaps two years, will be required before reliable conclusion can be made.

Experimental airplane seeding in Ephraim Canyon

During early October 1945, three areas comprising approximately 1,300 acres of deteriorated aspen and oakbrush range in Ephraim Canyon, Utah were seeded experimentally by airplane. Falling leaves covered the seeds. Careful observation of flying time and difficulties of seed distribution in calm and slight winds, and costs of operation were recorded and studied. A detailed manuscript report on these phases was prepared and furnished to the Washington office and western stations in June 1946. The annual report of 1945 contained a summary statement of findings. In September 1946 an examination of resulting stands was made.

A meandering transect of plots was used to sample the three seeded areas designated as follows: (1) Maple Creek (aspen) 56 plots; (2) the "Hole" (aspen) 40 plots; and (3) Oakbrush (oakbrush) 60 plots. Grass seedlings were counted on each plot of 9.6 square feet. On 61 plots, no grass plants were found to be established; on other plots the count varied from less than 10 seedlings to more than 60 per plot. The average number of established plots from reseeding were 0.89 per square foot in Maple Creek, 0.75 per square foot in the "Hole," and 0.74 per square foot in the Oakbrush area, including in the average the plots with no seedlings. It is possible that a considerable number of seedlings were missed in the count as they were small and as in many cases there was much litter on the ground.

The spring of 1946 had been at first unusually cold and then dry. Many seeds were found throughout that had not germinated and which appeared to be still in good condition. Except for the "misses" there were enough plants to make a reasonably good stand.

Oakbrush grows in clumps with openings between. Plot counts of grass seedlings were made in various locations with reference to clumps of oakbrush. The number of grass seedlings per square foot were as follows: North side 1.34, south side 0.13, middle of clump 0.95, and in openings between clumps 0.25 plants.

By 1947 somewhat more than half of the 1946 seedlings had died, as commonly occurs on loose seedbeds. The plants that survived had developed root systems and established themselves. In addition a whole new crop of seedlings appeared. In 298 plots of 9.6 square feet each on which the data were obtained, it was found that 29 plots bore only 2-year established plants, and 47 plots only 1947 seedlings. All other plots bore both 2-year and 1-year plants. Of the total plants, 78,53, and 58 percent of the plants were 1-year plants in Maple Creek, the Hole, and Oakbrush, respectively. Some ungerminated seeds were found, suggesting that another crop of seedlings may be produced in 1948. Average stands in 1947 were 1.09 plants per square foot in Maple Creek and 0.90 per square foot in the Oakbrush, ample for a good stand. In the Hole the average stand was 0.60 plant per square foot or just short of a good stand. The distribution of plants was much improved in 1947 over that of 1946 as shown by the 47 plots that bore only 1-year plants in 1947 and by the great number of plots that bore seedlings in addition to old plants.

Research at Willow Creek

Two plantings of 21 and 55 species each in duplicate range plots, were made in 1945 by hand broadcasting and disking on burned mountain brush at Willow Creek in Ephraim Canyon. In 1947 they were exposed to summer grazing by cattle and the degree of utilization recorded on August 6 when grazing was well begun and again on September 18 when it was completed. The six species most heavily utilized (highest preference) of 21 grasses and the six least heavily utilized (lowest preference) are given below for August 6 and September 18.

August 6

Six highest	Six lowest
Bromus inermis	Bromus carinatus
Elymus candensis	Agropyron cristatum
Agropyron repens	" intermedium
Arrhenatherum elatius #14	" smithii
" " #22	" subsecundum
Agropyron intermedium	Elymus glaucus

September 18

Agropyron repens	Secale montanum
" smithii	Stipa comata
Elymus canadensis	Agropyron cristatum
Bromus inermis	Bromus carinatus
Arrhenatherum elatius #14	Agropyron subsecundum
Agropyron intermedium	Elymus glaucus

The other planting of 55 species included legumes and weeds with grasses and gave the following order of preference:

August 6

Medicago glutinosa	Bromus carinatus
" sativa	Agropyron sibiricum
Onobrychis vulgaris	Elymus triticoides
Phalaris arundinacea	Agropyron intermedium
Trifolium pratense (M)	" subsecundum
Astragalus falcatus	Elymus flavescens
Trifolium pratense (C)	Festuca ovina sulcata
Melilotus alba (C)	Oryzopsis hymenoides
Onobrychis sativa	Viguiera multiflora

September 18

Medicago glutinosa	Stipa comata
" sativa	Agropyron cristatum
Trifolium pratense (C)	Bromus carinatus
Astragalus falcatus	Elymus flavescens
Elymus junceus	Hordeum bulbosum
Phalaris arundinacea	Viguiera multiflora
Trifolium pratense (M)	Oryzopsis hymenoides
Astragalus mortoni	Elymus glaucus
Elymus chinensis	Agropyron subsecundum

Clearly legumes were higher in preference by cattle than grasses. Certain grasses not suitable for the sagebrush zone do well in the mountain brush zone and have higher preference value than crested wheatgrass. Bromus inermis, Arrhenatherum elatius, Agropyron intermedium, and A. repens are high both in yield and preference.

Another point of great interest is that Agropyron intermedium had low preference in early growth but changed places from the poorest six to the best six in a list of 21 by mid-Spetember. In the list of 55 species it changed place from fiftieth on August 6 to twentieth on September 18, which was the seventh grass. Another new species, Elymus junceus, remains highly palatable throughout, being fifteenth, (fourth grass) on August 6 and fifth on September 18 (first grass). The species Agropyron repens is astounding in its performance, being an exceptionally strong sod-former, a very high yielder, and ranking first preference in 21 grasses and third grass in the 55 species list where it is ahead of several legumes.

Other Big-scale Plantings

Several forests in the Region have made or are now making seedings of appreciable size in the mountain brush-aspen zone to increase the supply of forage and to protect watershed values. The Manti, Fishlake, and Dixie Forests have made a number of seedings recently with very promising results in the way of getting stands. One sizable area where most of the topsoil had been eroded off gave only mediocre stands, thus illustrating one of the difficulties to be encountered.

A planting of 1,040 acres at Mud Flat on the Cache Forest seeded between 1940 and 1945 produced as a whole a good stand. The area can safely furnish forage at the rate of 2 to 3 acres per cow-month and is improving as the stand matures. Another 1,000 acres was seeded in 1946 and 1947 which, when established, will greatly relieve grazing use on the remainder of the watershed. The forage on the area is 5 to 8 times as great as before it was seeded.

Work on mountain brush ranges of Nevada is as yet in the early phases. An area of about 20 acres was accidentally burned in 1942 on Martin Creek headwaters of the Santa Rosa division of the Toiyabe Forest and seeded that fall as an administrative study to crested wheatgrass and smooth brome. It was open to grazing until 1945 when a 5-acre enclosure was built. Native species revegetated rapidly in the enclosure and reseeded species gave very good to excellent ratings (8 and 9 on the basis of 10 being completely successful) on areas that had little natural vegetation after the fire. The grazing capacity is more than 5 times as great on the reseeded as on similar areas not seeded.

At Goosey Flat on the headwaters of the Little Humboldt, Toiyabe Forest, somewhat more than 300 acres were seeded in 1945 at the same time sagebrush and mountain brush was removed by wheatland plowing. In 1946 most of the stand rated 4 to 5 with some better. It was, however, grazed that year before the plants were well established and in 1947 it rated only 2 or 3. An additional 600 acres were seeded in the fall of 1947. A triplicated series of species plots was also seeded under favorable conditions. Data will be taken in 1948 and 1949.

In southwestern Idaho as many as 30 research plantings and several administrative ones in the mountain brush zone have practically all failed to give satisfactory forage returns. All of the areas seeded were on fairly steep slopes of loose granitic soils from which much of the topsoil has been lost. The water-holding properties of these soils are very low. Protracted periods of low summer precipitation and high temperatures bring on excessive soil drought in such soils. Good stands of seedlings in spring have repeatedly deteriorated to poor stands of established plants by next spring. The plants that survived have in most cases made a good growth and been persistent. The continuing erosion on steep slopes and the failures so far to get stands have made clear that these loose granitic soils common in southwestern Idaho constitute a major problem in both reseeding and management.

In southeastern Idaho, good success from seeding trials has usually resulted. Along with 4,000 acres of reseeding in the sagebrush zone, D. V. Hagenbarth has seeded more than 1,500 acres in the mountain brush-aspen zone at his ranch on Sheridan Flat, 20 miles northeast of Dubois, Idaho. He has sought and followed carefully the recommendations developed by our range research. He says frankly his seeding has revolutionized and made successful his cattle and sheep operations. In 1944 the 1,500 acres carried 300 steers which in 3 months made a gain of 275 pounds a head; the same area supported in 1944, 200 cows with calves for 2 months and 1,500 ewes for 50 days. The range was conservatively used and has since continued in good production. The use equals about 1,800 cow-months feed from 1,500 acres. This high yield was helped by water spreading on part of the area and illustrates what many stockmen may accomplish by capitalizing on similar opportunities.

RESEARCH IN SUBALPINE ZONE

Subalpine zone areas need research studies and considerable administrative seedings, but work has just begun in that zone. Three serious problems that exist in alpine plant cover are receiving preliminary treatment to reduce competition in: (1) tarweed, (2) Wyethia, and (3) dandelion. Another difficult problem not yet under study is that of increasing vegetation on badly eroded areas of high elevations.

Tarweed--Previously, fall seedings made on tarweed areas have failed. The Great Basin Branch Station has found that spring cultivation of tarweed areas reduces this persistent annual enough to permit spring seeded grasses to establish themselves if enough precipitation comes during the summer to keep the grass growing. On this one area grass has kept tarweed from invading established stands of grass. It is necessary to study treatment on several sites and conditions of soil. Two new studies, one in Farmington Canyon, Wasatch Forest, Utah, and one on the Payette Forest, Idaho, were started last year.

Wyethia--The Targhee Forest seeded last fall 500 acres in the lower aspen zone much of it in Wyethia cover, which is low value range throughout the region. Wheatland plows were used to cut off the heavy roots. A study started by the Intermountain Station in connection with the large seeding includes moldboard plowing, deep and shallow wheatland plowing, deep and shallow two-way disking. Another plot will be plowed in spring to determine whether time of plowing makes a difference in degree of control. Some chemical spraying will also be done.

Dandelion--The Fishlake Forest is trying moldboard and wheatland plows for killing dandelion and the Intermountain Station is conducting a cooperative study along with this seeding. In Ephraim Canyon a study is being started to find out if less vigorous (and less costly) treatment than moldboard plowing will be effective.

STATUS OF RESEEDING IN SAGEBRUSH ZONE

Reseeding research for lands in the sagebrush zone has been under way for several years, and has developed a large body of reliable information. These findings and many conclusions based on them have been presented in detail rather fully in the annual reports for 1945 and 1946. While there is yet much to be done to fill in our information, the great framework has been erected and Region 4, U. S. Forest Service, has gone ahead with a vigorous program of "action" reseeding within the limits of available funds. Lands covered with sagebrush offer by all odds the greatest total areas of lands well suited for range reseeding. How to handle sagebrush preparatory to reseeding has been worked out in broad principles. Modification of new plows and disks for removing sagebrush has received much attention during 1947 and will receive more in 1948. Large areas of former sagebrush land are now occupied by cheatgrass which has received much recent study that is not yet conclusive.

It has been determined by consistent research that any land that produces a good stand of sagebrush is capable of producing good stands of crested wheatgrass, yielding one-half to one ton of air-dry forage per acre. This is 5 to 15 times as much forage as is produced on the ordinary type of sagebrush range. Because of this comparatively high yield, range reseeding has been shown to be the quickest and most effective means of restoring deteriorated plant covers to good forage production. Some sagebrush lands are too rocky, too rough, or on slopes that are too steep to permit the ready use of available machinery for removing sagebrush and seeding the grass. Low-lying lands are likely to bear considerable rubber rabbitbrush in the cover. These lands are much harder to handle than straight sagebrush lands because of generally having more compact soils and possibly some soil salts. Salt-weed edges of sagebrush lands are greatly more difficult to handle on account of the soil salts they contain. Not less than 16 million acres of sagebrush lands in the Intermountain region are available for reseeding, and in need of it.

On Sagebrush Lands

Such large areas of land highly suitable for reseeding exist in the sagebrush zone that wisdom dictates that the tracts with deepest soil and gentle topography be seeded first and the less suitable lands afterwards. It is recommended, however, that so far as at all possible, any lands that are accidentally burned over be seeded in the first fall after the burn.

Reducing competition

Most burned-over sagebrush lands are in good condition for drilling to grasses without further treatment. The most consistent stands and high yields of forage obtained have come on lands burned over and seeded the same season. By the second year after burning weeds generally occupy the area. The great success after burning and the comparatively low cost of clearing sagebrush by planned burning suggests that it would pay to make much wider use of this method, always of course, with provisions for controlling the fire to the area it is desired to burn over.

Among the mechanical means of removing sagebrush the wheatland plow has given most satisfactory results in effectiveness (70-90 percent removal) and in its comparatively low cost which is only about half of the cost of moldboard plowing. The Dixie pipe harrow can be used on land too rocky to permit the usual mechanical operations. Its effectiveness is only 35 to 50 percent, being suitable only where better methods are not applicable. Since railing is still less effective, removing only 20 to 40 percent of the sagebrush, it seems likely that this method will decrease in usefulness. The yield of grass on Raft River sagebrush flats was found to vary from 200 pounds to 1,600 pounds of air-dry forage for railing alone and for railing followed by burning which killed 98 percent of the sagebrush. Any method is successful roughly in the proportion of sagebrush it kills and so removes from later competition with grass.

Methods of seeding

Drilling has been found to give the most uniform seed distribution and most nearly the desired depth of one-half to 1 inch. Rates of seeding of 6 to 8 pounds of crested wheatgrass, the most suitable standard species, are recommended for drilling and 50 percent more for broadcasting. It is often feasible to broadcast in connection with wheatland plowing, in which case great care should be taken to get the seed covered, but not too deeply. Although three of the last four years gave good results from spring seeding, the 12-year record is decidedly in favor of fall seeding. Only unusually favorable precipitation makes spring reseeding anywhere nearly as safe on range lands in the sagebrush zone as fall seeding. Range lands with well-prepared seedbeds in a fine, firm condition hold moisture longer than rough, loose surface and may or may not warrant spring seeding of crested wheatgrass, depending on the reliability of spring moisture for 2 months after spring growth starts.

Response of species

On sagebrush land of valleys and lower foothills, crested wheatgrass has, over a period of years, given the only satisfactory results from standard species. It is fully winter-hardy and very drought-resistant. It has, however, one outstanding weakness, that of becoming harsh, strawlike and low in palatability once it has headed which it does about the time hot weather comes in earnest. Three promising new species of wheatgrass and Russian wildrye have been studied and found to remain green and succulent and therefore palatable much later in the season than crested wheatgrass. General observations have been made to this effect for the last two years. Now, however, the actual data are available and highly instructive (table 2).

Cheatgrass has a spread between "heads showing" and "seeds ripe" of 28, 18, and 34 days at the three stations; bulbous bluegrass 35, 15, and 15 days; crested wheatgrass 46, 56, 46 days; tall wheatgrass 51, 51, 67 days; stiffhair wheatgrass 62, 81, 49 days; intermediate wheatgrass (*), 76, 76 days; Russian wildrye 41, (*), 46 days. The last 4 new species not only have a much longer spread between "heads showing" and "seeds ripe" but also they do not become so unpalatable after seed maturity as cheatgrass and crested wheatgrass. Palatability of Russian wildrye remains good for a long time after seed maturity. Tall and intermediate wheatgrass showed flower stalks 40 days later than crested wheatgrass. Dates at which growth actually started were obtained only at Regina. Crested wheatgrass started 15 days earlier at Regina than did cheatgrass, intermediate wheatgrass, and Russian wildrye; and 10 days earlier than stiffhair wheatgrass.

Comparisons of the yields of crested wheatgrass and cheatgrass at Arrowrock showed that as an 8-year average crested wheatgrass outyielded cheatgrass by about 15 percent. Cheatgrass, however, was excessively erratic varying from 361 pounds per acre in 1943 to 3,461 pounds in 1944 or 9.6 times, whereas the variation in crested wheatgrass was from 1,090 pounds per acre in 1946 to 2,468 pounds in 1947, or 2.3 times. Crested wheatgrass is greatly more reliable as a forage producer in exceptionally dry years.

A compilation of all available data in Idaho showed that 6- to 8-inch spacing between the drill rows gave better occupation of the area and higher forage yields in the early years. In later years wide spaces were filled in with new plants by natural revegetation and equalized plant cover and yields.

(*) No observation

Table 2. Dates on which some well-known and four newly introduced species of grass began growth and reached seed maturity during 1947 at Regina, Blacks Creek, and Arrowrock, Idaho.

Species	Growth started	Regina		Blacks Creek		Arrowrock	
		Heads showing	Seed ripe	Heads showing	Seed ripe	Heads showing	Seed ripe
Well-known species							
Crested wheatgrass	Feb 5	May 15	July 1	May 15	July 10	May 15	July 1
Beardless bluebunch	Feb 20	May 11	June 25	May 15	July 1	May 15	Aug 1
Bearded bluebunch	Feb 15	May 1	June 25	May 15	July 1	May 15	Aug 1
Sandberg bluegrass	Feb 10	Apr 5	May 1	Apr 20	May 10	Apr 20	June 1
Bulbous bluegrass	Feb 7	Apr 10	May 15	Apr 25	May 10	Apr 25	May 15
Cheatgrass	Feb 20	Apr 20	May 18	May 1	May 18	May 1	June 3
Newly introduced species							
Tall wheatgrass	Feb 25	June 25	Aug 15	June 25	Aug 15	June 25	Sept 1
Intermediate wheatgrass	Feb 20	June 25	-	June 1	Aug 15	June 1	Aug 15
Stiffhair wheatgrass	Feb 15	May 1	Aug 1	June 1	Aug 20	June 17	Aug 5
Russian wildrye	Feb 20	Apr 20	June 1	-	June 15	May 1	June 15

Cheatgrass

Reducing competition from cheatgrass

A somewhat closer examination of the results of various treatments for reducing cheatgrass competition before reseeding was made in 1947. The experiment, as to the effect of the time at which cheatgrass was burned off had on the spring stand next year, was completed. Burning about June 15 or July 15 so reduced the stand of cheatgrass that seedings made in fall after the burn suffered little competition. In dry years, burning on August 15 and September 15 gave nearly as good control as those on June 15 and July 15, but in 1947 the summer was rainy and late burnings allowed greater competition as they produced more than twice as many cheatgrass plants.

The stands of crested wheatgrass, where seeded on land heavily covered with cheatgrass were in almost direct proportion to the reduction in cheatgrass. Reduction in cheatgrass plants from various preparatory treatments was as follows: moldboard plow (any season) 95 to 98 percent (most effective but very costly); wheatland type plow (spring or late fall) 80 to 98 percent; light disk or shallow tillage (spring or late fall) 40 to 75 percent; springtooth harrow (spring or late fall) 30 to 70 percent; spiketooth harrow (late fall) 5 to 30 percent; deep-furrow lister drilling (late fall) 50 to 85 percent; planned burning (early summer) 75 to 95 percent; and drilling (fall) 5 to 30 percent. Effective tillage treatments to control cheatgrass had to come early in spring before cheatgrass seeds mature or in fall after germination.

Relationships of sagebrush, cheatgrass, and fire

The present ecological information on cheatgrass has been summarized as a basis for reseeding and range management procedure. Many gaps in the information are yet to be filled in by careful research. Such things as its period of growth, seeding habits, and its response to common treatments are well known. We are rapidly accumulating knowledge of its competitive relationships. For example, it is known from numerous seeding plots that the rapid growing seedlings of cheatgrass are too vigorous for seedlings of crested wheatgrass and other commonly used grasses. Cheatgrass must therefore be thinned before reseeding. Once crested wheatgrass plants are established, they crowd back cheatgrass from 8 to 20 inches. Almost all reseeded areas have shown that a good stand of crested wheatgrass reduces cheatgrass to a minimum but does not eliminate it entirely, as a few greatly suppressed cheatgrass plants are always found. When the crested wheatgrass or other perennial grasses are weakened from any cause, the cheatgrass promptly fills in and commences reoccupation to the ecological detriment of the reseeded species.

Cheatgrass responds to the burning of brush by occupying the area next season. It also greatly increases the fire hazard, increasing the danger and making fire more difficult to suppress or control. Many thin stands of reseeded crested wheatgrass bearing a heavy mixture of cheatgrass have, however, been much benefited by a fire which removes or greatly decreases competition from cheatgrass. In as many as a dozen cases, crested wheatgrass thickened as much the first year after such a fire as it did on adjacent unburned range in 3 to 5 years.

Big-scale Reseeding

Region 4 reports that the Forest Service has seeded to the end of 1946 in the Region 4 part of Idaho, Nevada, Utah, and Wyoming 116,901 acres and in 1947 an additional 29,718 acres, or a total of 146,619 acres. In addition private stockmen have seeded more than 350,000 acres in Utah, approximately 300,000 acres in Idaho, about 20,000 acres in southwestern Wyoming, and less than 10,000 acres in Nevada. Nevada stockmen are just finding out how helpful reseeding may be in providing feed.

One big-scale cooperative seeding at Benmore, Utah used for experimental grazing studies, and another in Ruby Valley, Nevada developed as an administrative study, both make it possible to reduce spring and early summer grazing on adjacent national-forest land by grazing cattle on these lands below forest boundaries.

Grazing Reseeded Lands

The Benmore grazing study was revised this year to include 24 pastures and made into a two-block study of all treatments which include time, intensity, and methods of grazing. Data from previous tests involving 18 pastures were summarized in last year's (1946) annual report. The addition of 6 new pastures to the study necessitated a reassignment of pastures in order to randomize the treatments. The committee in charge decided on uniform time and intensity grazing for 1947 in order to equalize the pastures and equate approximately their grazing capacities. All pastures were grazed for the full spring period at moderate intensity. The kinds of vegetation data to be taken were also revised somewhat in keeping with previous experience. A new set of work plans is being prepared by the cooperating agencies to cover the experiment as revised.

The data resulting from 1947 cover the two major aspects of (1) cattle gains and (2) vegetation responses to grazing, including forage yields and utilization. Gains on 600 cattle plus young calves were obtained by weighing each animal, carefully tagged, in and out of the pastures after uniform shrinking. It was not known just what percentage utilization should be aimed at or how closely vegetation ought to be grazed. It was decided to aim at 65 percent utilization of crested wheatgrass, and to bring the grazing use in all pastures as nearly as possible to that figure. An approximate forage inventory by species was made at the time grazing began.

Cattle gains and forage utilization

Cattle weights kept pace with gains of previous years for the 63-day period from April 16 to June 18. They averaged 1.9 pounds per day for animals over 6 months of age and almost as much for calves under 6 months of age.

When grazing began, crested wheatgrass and western wheatgrass had leaves 5 inches long and were producing on areas where a full stand had developed 950 and 360 pounds of green forage. Stands of western wheatgrass were extremely irregular, and in several pastures this species barely occurred. Crested wheatgrass stands were spotted in all pastures and the yield averaged only 420 pounds per acre throughout. Cheatgrass occupied most of the spaces where no crested wheatgrass grew and filled in where the stand was thin. At the time grazing began, cheatgrass was only an inch tall and cattle could not graze it. Since the spring was cool and moist, crested wheatgrass grew rapidly. Cheatgrass grew very slowly for a time and then rapidly. By May 20 cheatgrass had produced seeds and started to dry.

At the end of the grazing season another forage inventory was taken and the amount of feed consumed was calculated. The percentage dry weight in the various species was also determined (table 3).

Table 3. Acre yields of green weight and air-dry weight, and green weight of forage by species consumed by each cow per day. Benmore, 1947.

Species	Yield-green weight (lbs. per A)	% Air-dry weight	Yield-air-dry weight (lbs. per A)	Eaten per day lbs. green wgt. (per head)
Crested wheatgrass	691.2	50	345.60	32.77
Cheatgrass	77.60	85	65.96	1.44
Western wheatgrass	11.97	50	5.99	0.42
Bulbous bluegrass	16.56	100	16.56	0.38
Weeds	10.83	30	3.25	0.12
Rubber rabbitbrush	41.91	45	18.86	0
Sagebrush	24.74	50	12.37	0
Total	874.81		452.03	35.13

Percentage utilization was obtained by taking data by species on 60 plots per pasture. Utilization by pastures of crested wheatgrass ranged from 58.17 to 65.35 percent and averaged 62.18 percent. For the other species the corresponding figures were cheatgrass 3.77 to 36.65, average 23.18; bulbous bluegrass 10.76 to 51.95, average 17.50; western wheatgrass where it occurred 35.10 to 52.45, average 43.55.

Since the growing season of 1947 had considerably more precipitation than average, crested wheatgrass grew right up until the cattle were removed. Continuous growth is likely a factor in getting somewhat less than 65 percent utilization. On this assumption, utilization during a dry year would tend to exceed somewhat the 65 percent that was aimed at.

Seasonal grazing capacity

The pastures were fall grazed from October 15 to November 28. Snow interrupted the grazing before the utilization aimed at had been achieved. Spring grazing furnished 1,317 cow days and fall grazing 448 cow days per 100-acre pasture, a total of 1,765 cow days. Calves under 6 months of age at the beginning of the grazing period were not counted. This amounts to a cow month of feed (plus calves) for each 1.74 acres. The utilization was very moderate, perhaps too moderate, but that is one of the points the experiment, when complete, is designed to establish.

The grazing capacity is approximately 11 times that of unseeded open range on nearby similar sites and more than 20 times as great as that on large areas of sagebrush range in parts of Utah where the annual precipitation is approximately the same, 11 to 12 inches. The supervisor of the Wasatch Forest has told the permittees on the Vernon division near Benmore, where about 900 head are permitted, that the use of the pastures has allowed the forest range to improve so much that no reductions in numbers are needed.

Nevada grazing experiments

Near Wells, Nevada, a small 2.2-acre pasture at the Ruby substation, has been grazed for 7 successive years at the rate of 1.05 cow months per acre. The utilization has been near 60 percent. Because of the small size of this area, it is not so reliable as a measure of forage production as 2,400 acres grazed at Benmore. It does indicate, however, that in the foothills of the Ruby Mountains good forage yields may be obtained.

About 30 miles south of Wells in Ruby Valley, Nevada an 800-acre seeding made in the fall of 1945 now bears a good stand of crested wheatgrass. This was a cooperative seeding made for the purpose of affording relief to nearby Pole Canyon allotment on the Humboldt National Forest which is used too heavily in the spring and early summer by 623 head of cattle. In 1947 the Ruby Valley area was grazed by 400 cattle for 24 days (May 20 to June 12); that is, 320 cow months of feed were taken.

The area is divided into three fields of which the acreages and forage utilization were south pasture 240 acres, 55 percent utilization; middle pasture 320 acres, 30 percent; and north pasture 240 acres, 35 percent. This is an average utilization of 39 percent. As a rough calculation the 800 acres would have furnished 480 cow months at 60 percent utilization. Yields will likely improve for the next 2 or 3 years as the plants reach maturity. Somewhat earlier grazing would make better use of the grass, as many plants headed shortly after grazing began. Heat and flies brought an end to the grazing on June 12 even though utilization was low.

A 400-acre cooperative seeding and administrative study was seeded in the fall of 1946 near Dinner Station, 20 miles north of Elko, Nevada. This area is not yet ready for grazing.

RESEEDING FOR RELIEF ON WATERSHED RANGES

The Benmore pastures, the Ruby Valley area, and a dozen big-scale seedings on lower edges of national forests by the Forest Service, large seedings by the Bureau of Land Management, the Soil Conservation Service, the military forces, and by private individuals are now growing large quantities of feed. Great numbers of livestock that have hitherto grazed in summer on watershed ranges can now find better, more accessible feed on foothill and valley lands. This permits relaxation in grazing use on the watersheds.

The Station has aided Region 4 in making an estimate of total land suitable for, and in need of, range reseeding. By states in Region 4, the acreages largely in the sagebrush and mountain brush zones are Idaho, 5,000,000 acres; Nevada 4,000,000 acres; Utah 6,200,000 acres; Wyoming (in Region 4) 600,000 acres; and California (in Region 4) 200,000 acres. The total is 16,000,000 acres in Region 4.

When any large part of this acreage is seeded, grazing on watersheds may be greatly relaxed and in many cases largely eliminated.

BRUSH ERADICATION WITH CHEMICAL SPRAYS

The serious problem created by the invasion of rabbitbrush and sagebrush in areas of reseeded range land was described in the 1946 annual report. That report also noted that preliminary treatment of 2,4-D spray had been applied by hand spraying.

In the spring of 1947, it was found that early application of spray while the plants were in a period of rapid growth, had killed more than half the plants and reduced growth on the others to a few green sprigs. Spraying of brush after growth had stopped (September 28) produced minor effects. Rabbitbrush plants which had been clipped with hand pruning shears at the time of spray application practically all sprouted vigorously in 1947. Clipping of rabbitbrush as by mowing seems a much less promising means of control than spraying. Grass showed no visible effects of being sprayed.

In August 1947, a power sprayer was used to make an experimental spraying of heavy rabbitbrush on a reseeded range of the Moon Lake drainage, Wasatch National Forest, near Kamas, Utah. Spraying was done in early August during rapid growth. "Weedone," a commercial spray was used at the rate of 1 to 60 gallons of water and 1 to 100 gallons of water. A spray being used for commercial spraying of weeds on farm land and designated as 2,4-33 was used for another treatment. Plots in a native cover of mixed sagebrush, rabbitbrush, and some herbaceous species were also treated by each spray mixture. The sprayer was obtained as a loan from the county agent of Summit County, who aided in our spray applications.

In late September 1947 the brush on treated plots had the appearance of being heavily injured. The top growth of all native broadleaved perennials seemed to be killed back. The weed, Canada thistle (Cirsium arvense), however, was only mildly injured.

Accurate data will be taken in 1948, at such a time as the permanent effects of the treatment are manifest.

IMPROVED MACHINERY FOR RESEEDING

The Intermountain Station is cooperating with the Equipment Laboratory and the western Regions and Forest Experiment Stations in modifying machinery to make it more suitable for range reseeding. The available machinery, -- wheatland type one-way disk, ordinary disks, two-way disks, drills, etc. -- have all been developed for smooth farm land without rocks or heavy brush, and are not heavy enough or sturdy enough for rough range work. During 1947, the Equipment Committee has had several meetings and the Equipment Laboratory is building six plows of an improved type in which the good points of the wheatland and the Australian stump-jump plow are combined and in which all breakable parts are greatly strengthened.

The Station also aided in conducting tests on the stump-jump plow and determined that it is highly effective in removing sagebrush on ground too rocky for the wheatland.

The Station aided Region 4 in putting on an equipment school on the Fishlake Forest September 4 and 5, to which all Utah forests sent their seeding men. In demonstrations of sagebrush removal conducted during the school, the stump-jump plow removed 92 percent of the sagebrush, the wheatland plow 79 percent, ordinary two-way disk 78 percent, an A-shaped rail 36 percent. This test indicated great promise for the two-way disk, an ordinary farm implement carried in stock by dealers of standard farm machinery. The rails did so poorly that considerable discussion developed as to whether it was really worthwhile to use rails. Although a power seed broadcaster was tested, and did good work as broadcasting goes, many of the men attending the school favor plowing sagebrush during the summer and drilling the seed at the right period in a second operation. This avoids plowing sagebrush after it is in seed and also allows time for the seedbed to settle. This method gives much more uniform distribution of the seed and makes it possible to get more of the seed at the right depth.

Plans for 1948

Plans for 1948 are to prosecute as vigorously as possible (a) field investigations needed to fill in gaps in information for the different vegetation zones, to make progress in going projects, and to prosecute new and enlarged studies; and (b) preparation of manuscripts to present results of completed studies, or of such studies as lend themselves to publication in progress reports.

A - Field investigations

Mountain brush and subalpine zones--Studies in the mountain brush-aspen zone are now in full swing in Utah, have passed through the preliminary stages in Idaho, and have begun in Nevada. It is planned to give special attention to the following phases:

1. Continue the present studies, enlarge them and begin new ones on the removal of mountain brush, and of mixed mountain brush and sagebrush.

2. Enlarge studies on loose, granitic soils in Idaho and start new ones to determine how to circumvent failures such as have occurred in the past.

3. To begin new studies in Nevada.

4. To continue subjecting old and new species and strains to a thorough study of their suitability in the principal mountainous zones.

5. To enlarge the investigations in the subalpine zone, particularly in removal of competition from tarweed, Wyethia, dandelion, and other weeds.

6. To continue observations of airplane seedings wherever and by whomever made; and to continue to take data on the experimental reseeding in aspen and oakbrush in Ephraim Canyon until establishment is completed. Prepare a report on airplane seedings.

Sagebrush zone--A large body in information has been built up for seeding in the sagebrush zone. "Action" programs for reseeding are in operation by the Forest Service, Bureau of Land Management, Indian Service, and private stockmen. Some gaps in information need to be filled in and heavier machinery is needed,

1. To complete the taking of data on old studies and prepare results for publication. A considerable number of studies will be left for several years to furnish data on how long stands last and the extent to which native species come back.

2. To continue the investigation of how well new species and new strains are adapted to various site conditions.

3. To determine the effects of chemical sprays on the control of rabbitbrush, sagebrush, and other brush in reseeded stands.

4. To determine the most feasible methods of establishing reseeded perennial grass stands in range lands occupied by cheatgrass.

5. To investigate the success of major species recommended for reseeding when competing with cheatgrass.

6. To continue grazing studies at Benmore and develop work plans for the revised design of conducting the experiment. Other data on grazing reseeded areas, both as regards grazing capacity and preference value, will be gathered wherever the opportunity is presented.

Salt-desert shrub zone--Preliminary studies have been established in the salt-desert shrub zone which comprises most of the winter range lands in Utah and Nevada. It is planned to continue and enlarge these studies. A vigorous program of collecting species for reseeding under desert conditions will be continued and strengthened.

FLOOD CONTROL SURVEYS

Sevier Lake watershed report

The survey report and appendix material were completed in preliminary draft form during the early part of the year. The report was then forwarded to regional offices of the Forest Service, Soil Conservation Service, Bureau of Reclamation, and Corps of Engineers for review and comment. After minor revision as a result of this review the report was forwarded to Washington for final review and comment by the Forest Service. All appendix material has been processed in final form in sufficient amounts for final distribution but reproduction of the report proper has been withheld pending Washington approval.

Mt. Pleasant flood control project

After the severe flood of 1946, the people of Mt. Pleasant, Utah recognized the need for immediate action to repair the damaged stream channel and protection works in order to provide better flood protection to their town. By June 1947 a fund of $20,000 was raised from town, county, and state sources, and personnel from the State Road Commission were loaned to direct the project. In response to a request for cooperation, the Station furnished an engineer to assist in the technical planning of the project. The features of the project were coordinated as closely as possible with the proposed flood control program for Mt. Pleasant as set forth in the station's Flood Control Survey report for the Sevier River Basin, Utah. The project which only included downstream Channel and debris dam construction was completed in September.

Study of transmountain diversions

There is a dearth of quantitative data on the effect on stream channels of the importation of additional spring runoff through transmountain diversions into small headwater basins in the intermountain area although it has been qualitatively observed by many. It appears that in many cases this additional flow has contributed to accelerated stream bank erosion and channel degradation with resultant flashier flood peaks and increased sedimentation rates downstream. In order to obtain a quantitative measure of this action on headwater stream channels a detailed engineering survey of Cottonwood Creek near Fairview, Utah for which a transmountain diversion is proposed, was made by a member of the Division of Engineering, R-4, under the direction of the Flood Control Division. Permanent reference points for typical channel sections were located so that a resurvey can be made after the proposed transmountain diversion into the headwaters of this stream has been installed.

Productivity value of water

Investigations of past methods of evaluating the loss from sedimentation of irrigation reservoirs indicate that the criteria used do not measure the values involved. The common practice has been to use the sales value of the water, the cost of constructing the dam or the replacement cost of building a new dam at a new site when a site is available. Not one of these measures consider the value of the reservoir site or the large created values represented by the developed irrigated economy in the valley below.

Flood control is a social program financed largely by Government expenditures for the benefit of the people. Therefore, cost-benefit evaluation should reflect, insofar as possible, the effects of the proposed programs upon the welfare of society. In developing the Sevier Lake Flood Control Report the losses caused by reservoir sediments and the benefits resulting from reduction of such sedimentation were evaluated by using the productivity value of the water lost or conserved. This measure of value is defined as the difference in the farm market value of crops produced between irrigated and nonirrigated land in terms of dollars per acre foot of water released from the reservoir for irrigational use. It is computed by subtracting the average gross value of crops per acre produced on dry land from the average gross value of crops produced per acre on irrigated land within the watershed and dividing the product by average acre feet of water released from the reservoir per acre of land irrigated.

The use of the productivity value of water to measure the loss occurring from the deposition of sediment in reservoirs evaluates in part the wealth created by the irrigational development. Justification of its use in cost-benefit analyses is based on the assumption of basic future conditions. First, reservoir sites are limited in number and therefore irreplaceable natural resources. When all available sites are used, continued sedimentation will gradually destroy not only the farm business dependent upon storage water, but the total economy of the watershed as well.

Second, the increase in crop production resulting from application of water to land is the product of increased use of the factors of production labor, capital, water, and a more intensive use of land. The developed product starts a flow of crop in one direction and a flow of payments in another direction with the farmer as the focal point. The availability of water from the reservoir makes possible the employment of additional labor and capital within the watershed and outside of the watershed. Loss of the usable water supply will force labor and capital to move into other uses or other areas. It is assumed that in the future:

(1) As sediment displaces water storage capacity in reservoirs and all dam sites are utilized the usable supply of water will gradually decrease and force a reduction in amount of land irrigated. Labor and capital so employed in excess of dry land requirements, including the labor and capital employed to handle, process, and transport the crops and supply the needs of the farmer, will be forced to move.

(2) Capital invested in irrigation works, land development, roads, buildings, etc. in excess of dry land operation requirements will not be movable and will be written off as a loss.

(3) Land will be relegated to a lower use--produce less.

(4) The influx of labor and movable capital (1) into other employment and other areas will compete with capital and labor in the other uses and areas and reduce the per unit earning power so that total earnings of labor and capital will be reduced by an amount equal to the former earnings of the labor and capital forced to move or

(5) The market value of agricultural products will increase, due to the smaller supply, and the increase will be sufficient to equal the value of crops formerly produced under irrigation, the production of which is curtailed because of lack of irrigation water.

(6) A combination of (4) and (5) will take place but the result will be the same.

The result, based on the above assumptions, will be a loss to society at least equal to the difference in the market value of crops produced on irrigated and nonirrigated land.

The use of the productivity value of water, as defined above, to measure the loss from sediment depletion of storage capacity still does not consider the loss to the segment of society which derives its income partially or wholly from handling, processing, and transporting irrigation crops after they leave the farm.

Boise River watershed survey

Revision of the survey report required a considerable amount of field work all of which was completed during the year. This included: (1) reexamination and reappraisal of damages to irrigation systems; (2) bringing up to date range use by livestock and big game; (3) checking of plant cover and erosion conditions on the watershed so as to reflect changes which have taken place since the original field work was done, including detailed mapping of cover and erosion on 6 small watersheds totaling 60 sq. mi.; (4) reappraisal of road damage; (5) revision of channel and road improvement programs; (6) assisting in a sediment survey of Arrowrock Reservoir (initiated by the Bureau of Reclamation in cooperation with the Corps of Engineers); (7) resurveying of ranges across Diversion Pond and at bridges or other typical sections of Boise River main channel; and (8) reconnaissance surveying of sediment in Pleasant Valley and Orchard Ponds on Indian Creek.

Adjustments of the original survey data were made to reflect recent flood control programs by the Corps of Engineers through the authorized Lucky Peak Dam and also flood control features of the Anderson Ranch Dam now under construction by the Bureau of Reclamation. Personnel assigned from the Soil Conservation Service region, Portland, consisted of a sediment specialist for 2 months and an engineer for 2 weeks. At the close of the year, the revised report and appendix material was written in first draft form.

Sediment production: Six small drainages on the Boise River, Idaho, gaged by the U. S. Geological Survey in 1939-40, were compared in order to estimate sediment production from forested and range watersheds under varied land use. These watersheds totaling 39,200 acres were mapped in detail during June 1947; cover, erosion, soils, slope, etc., were shown on an aerial photo base with delineations as small as a few acres. From these observations, four condition classes were recognized within four cover types--forest, browse, sage, and herb. Channel cutting, which could not be directly measured, appeared associated with upstream conditions. The rate of sediment production for each condition and type of cover was then estimated from published daily runoff and sediment loads.

The total sediment load of these small streams appeared to vary with the stage. It was found that sediment loads would correlate with discharge if groundwater was separated from the hydrographs. The following equations between daily sediment loads (S) in tons and daily discharge above base-flow (Q) in second-feet were determined:

Sediment Equations

Watershed	Area (Sq. mi.)	Land use	Equation
Bannock Cr.	4.5	Commercial forest	$S = 8Q^{1.67}$
Pine Cr.	6.1	Cutover "	$S = 14Q^{1.69}$
Granite Cr.	4.8	Cutover & burned	$S = 19Q^{1.70}$
Cottonwood Cr.	21.4	Fair for. & range	$S = 15Q^{1.24}$
Cottonwood Gulch	16.0	Depleted range	$S = 38Q^{1.14}$
Grouse Cr.	8.0	Badly " "	$S = 50Q^{1.22}$

The coefficients of these equations appear to reflect the condition of the watershed, while the power function seems to depend upon drainage basin size, slopes, and channel characteristics. Average power functions of about 1.7 apply to small drainage areas, 1.2 to the larger areas, while for suspended loads gaged on main tributaries of the Boise River, the power may drop to 1.0.

Sediment coefficients for each condition class of cover to satisfy the above equations are shown below.

Sediment Coefficients, 1939-40

	Cover condition class			
Cover type	Good	Fair	Poor	Very poor
		(Tons per c.f.s., daily)		
Forest	5	5	15	-
Cut-over or burn	-	13	40	-
Browse	-	10	25	-
Sage	-	25	40	50
Herb	-	-	60	150

Long-time average sediment production depends not only upon watershed and associated channel conditions, but also upon a normal duration of runoff to transport the sediment. The relative amounts of flash runoff above groundwater rates during either 1939 or 1940 were also estimated for each condition class and the maximum shown below:

Relative Flash Runoff, 1939-40

	Cover condition class			
Cover type	Good	Fair	Poor	Very poor
Forest	0.13	0.23	0.32	-
Cut-over or burn	-	0.39	0.47	-
Sage-browse	-	0.23	0.47	0.62
Herb	-	-	0.78	1.07

These estimated coefficients were verified by weighing each cover condition by the areal extent on major tributaries of the Boise River as mapped in 1939. Normal duration of flash runoff was established from over 30 years of runoff records at stations on the Boise River. Power functions were estimated at from 1.0 to 1.2 depending on the drainage area. A summary of the estimated sediment prodution from the Boise River is given below:

Estimated Sediment Production, Boise River Watershed

Watershed	Area (sq. mi.)	Normal flow Duration (cfs X days/sq.mi.)	Sediment coefficient (tons/cfs)	Normal annual sedimentation (tons)	(A.ft.)
North and Middle Forks at Twin Springs,	830	20.0	11.0	183,000	93
South Fork at Lenox	1,040	9.4	15.3	150,000	77
Arrowrock Res., local inflow	290	12.3	23.5	65,000	135
Moores Creek near Arrowrock	430	11.3	14.8	133,000	68
				Total	373

The estimated rate of sediment production from the Boise River Watershed agrees closely with the estimated loss of storage in Arrowrock Reservoir and also compares with a survey of Black Canyon Reservoir on the adjacent Payette River.

Survey of Arrowrock Reservoir--Earlier drafts of a flood control survey report for the Boise River watershed utilized data pertaining to the sedimentation of Arrowrock Reservoir which were based on estimated and not actual measurements. Since the rate of sedimentation of this important reservoir is a vital factor in analyzing the flood problem and in proposing and evaluating a remedial program, it was decided that measured results were needed.

This problem was presented to the Hydrology Section of the Bureau of Reclamation which agreed to change its survey plans in order to complete a detailed sediment survey of this reservoir using a fathometer during the year so that the results would be available for our flood control report.

The station cooperated in this survey by furnishing a geologist and sedimentation specialist for the duration of the survey, drafting services totaling 14 man-weeks, 1-2 S.P. assistants throughout the survey, and by providing a boat, outboard motor, and miscellaneous equipment. Additional assistance to the Survey was also provided by rodmen assigned from the Corps of Engineers, Portland district. Preliminary survey results will be released by the Bureau of Reclamation in the spring.

Fountain River and Cherry Creek (Colo.) surveys

The work of revising survey reports on these two watersheds was conducted concurrently under one project leader. Since the original field work on the Fountain River watershed was done in 1937 and 1938 and on Cherry Creek watershed in 1939 and 1940, a considerable amount of additional field work was necessary. Most of the land on both watersheds is privately owned, consisting of both grasslands and cultivated cropland. It was therefore necessary to request assistance from the Soil Conservation Service which was provided by the assignment of two conservationists, one economist, one hydrologist, and one geologist.

Principal field tasks included: recalculation of cover conditions; analysis of damages by floods of low magnitude which had not been studied during original survey; revision of remedial program; bringing up to date information on floods, flood damages, and hydrology; consideration of effects of program on John Martin Reservoir in Fountain survey; removal of program effects on Kenwood Dam and inclusion of effects of Cherry Creek Dam in Cherry Creek survey; appraisal of road damages and recalculation of improvement program for roads and channels; and inclusion of works of improvements for the protection of city of Manitou.

Field work was delayed somewhat by lack of personnel especially in hydrology and sedimentation. All necessary field tasks were finished in late summer and at the close of the year most of the appendix material on Cherry Creek had been completed in the first draft form. Writing of the report itself was awaiting completion of analysis of hydrological and sedimentation phases.

Flood-producing storm of May 10, 1947--On May 10, 1947 a flash flood occurred from a portion of the Front Range northwest of Colorado Springs, Colorado. It caused the loss of one life and $195,000 damage to the town of Manitou Springs and surrounding areas.

The flood-producing storm centered on the south end of the Rampart Range a few miles northwest of Manitou Springs. An area of 14 square miles experienced more than 5 inches of rainfall in a 3-to 5-hour period.

Principal items of damage, other than loss of life, included municipal damage to Manitou Springs from both flood water and sediment, washouts and interruptions of traffic on roads and railroads, destruction of bridges and drainage facilities, damage to water supply systems, loss of personal property, and injury to suburban improvements.

Although flood peak discharges were not exceptionally high, channel restrictions and encroachments prevented the unobstructed passage of the flood water. Manitou Springs, in which channel restrictions are most common, suffered the greatest damage. Williams Canyon, which drains an area of less than 1,900 acres, caused considerable damage before it entered Fountain Creek within the town limits. The estimated peak discharge from Williams Canyon was not over 600 c.f.s. but the capacity of the channel in town was so obstructed that most of the flow occurred outside the channel.

Prior to the storm, the area had experienced a period of general cloudiness and scattered rains. Snow had been melting rapidly at the higher elevations and it is probable that the soil profile was fairly well saturated. An inspection of the watershed immediately following the storm revealed that considerable surface runoff had occurred on the exposed south- and west-facing slopes. Rapid return flow appeared to have augmented surface runoff.

Wasatch Front watershed survey

Because of the separation of the watershed into two survey areas and the many changes in watershed conditions and survey procedure which have taken place since 1941, a new survey work outline was prepared prior to the start of field work. This work outline was reviewed and approved by the Soil Conservation Service.

Field work began as soon as weather and road conditions permitted entry into the mountain country. Sample tributaries were selected, plant cover-erosion categories determined, mapping initiated, and detailed plant cover-erosion survey and mapping of sample tributaries were started. As soon as the remodeled infiltrometers were available in midsummer additional infiltration tests were made on important soil cover complexes which had not previously been tested. The engineering aspects of the flood problem on cropland and the remedial program needed were studied by a member of the Soil Conservation Service assigned to the Forest Service for approximately 1 month. Only about 5 percent of the watershed under study is cropland.

Road damages and needed works of improvement were surveyed and reported upon by a member of the Engineering Division R-4, detailed to the Flood Control Survey Division.

Field work was handicapped to some extent by shortage of personnel occasioned by assignments to other surveys, changes in project leadership, physical difficulty of getting over high mountain country, and lack of adequate transportation. However, at the close of the year all of the necessary field work dealing with land use and condition was completed with the exception of about 1 month of work by a 2-3 man crew on category mapping and about 6 weeks of work by a similar crew on detailed mapping of sample tributaries. Assembly and analysis of flood damages, hydrological analysis, formulation of a recommended program, determination of structural program other than on roads, and preparation of the report remain to be done.

Infiltration investigations--Infiltration investigations were conducted on the Wasatch Front watershed during the late summer of 1947 as a part of the flood control survey. A modified F-type infiltrometer, as designed by the Division of Forest Influences, was used in these studies.

Calibration of the apparatus and office work preliminary to actual field tests, including the development of site evaluation techniques, drafting of forms, etc., were completed in August. Because of the newness of equipment and because of limited time only a limited amount of investigation was undertaken. To provide the subject matter for a hydrologic evaluation of range improvement program, the study was designed to determine the relative infiltration on good grass sites and poor weed sites.

Actual infiltration tests were started in late August and were stopped in the early part of October during which time 21 acceptable runs were made. The infiltrometer, operated by a 2- to 3-man crew, was altered in design by discarding several pieces of equipment in an effort to streamline procedures so as to better fit the needs of Flood Control Surveys. Recognized techniques of site evaluation were followed in most cases and constituted as complete an analysis of soil and vegetative characteristics as the equipment available, materials on hand, and time available would allow.

Rainfall and runoff were calculated to include corrections for slope, silt, and surface storage with the difference, rainfall minus runoff, plotted as the actual infiltration-capacity curves. Inspection of these curves reflected a relationship of nearly two to one in favor of dense grass cover over sparse weed cover, other variables remaining constant.

Further investigation of these curves and vegetative and soil characteristics showed positive correlations between infiltration and plant density, and infiltration and litter plus basal areas of vegetation; and also a high negative correlation between infiltration and the percentage of bare ground exposed to the impact of raindrops. Apparent relationships between infiltration and various soil characteristics were likewise tested for validity by correlation-coefficients but were found to lack statistical significance. Some of this was believed to be due to the small number of samples.

Two runs of exceptional interest were encountered during the work. One plot on a reseeded grass area (mainly tall oatgrass and crested wheatgrass) with a density of approximately 70 percent had an infiltration capacity in excess of 5.6 inches per hour. Nineteen inches of rain was applied at the above rate and while surface depression storage was evident, no runoff was recorded or visible. The soil on this site, alluvial in origin from sandstone and quartzite, is a brown friable loam of greater than 4 feet depth. The other run was on a wheatgrass site with a density of approximately 45 percent, in which the infiltration rate remained above 5 inches per hour for 1 hour and 50 minutes whereupon it began to fall rapidly for 40 minutes when it became stable at approximately 3.5 inches per hour. Here the soil, residual in origin from Wasatch conglomerate, is a reddish brown friable clay loam overlying at 18 inches, a red plastic clay subsoil. In both cases slopes were approximately 10 percent.

Sedimentation survey of Pineview Reservoir (Ogden River)

A sedimentation survey of Pineview Reservoir on the Ogden River was made during the early part of 1947. This reservoir is not located in that part of the Wasatch Front Watershed now being surveyed. However, when the Bureau of Reclamation decided to drain this reservoir during the winter of 1946-47, opportunity presented itself for surveying the sediment deposits in the reservoir in a much easier and less costly manner than would be experienced under normal reservoir operations. Sediment was measured with a spud on areas under water and with auger and spade on areas above water. The range method of observation was followed and data were plotted on enlarged (9" = 1 mile) aerial photographs.

The drainage area is considered to be 310 square miles mostly of mountain land although there are included small areas of broad flat valleys of the tributary streams. 195 acre feet of sediment were measured which imply that the reservoir has been receiving sediment at the comparatively low rate of about .06 acre feet per square mile per year since water storage began in 1936.

Watershed surveys by the Soil Conservation Service, Queen Creek watershed

In the Queen Creek (Ariz.) survey the information gathered by a Forest Service representative R-3, was submitted to the Soil Conservation Service and was used by that agency as a basis for that part of the survey report dealing with the mountain and foothill land on this watershed. Preliminary draft of the report and appendix material were reviewed and comments submitted to the Soil Conservation Service. This included consideration of the report by both R-3 and the Southwest Station. The Flood Control Survey Division at this station arranged for such a review and summarized the comments from all three groups. This procedure was also followed on the final field draft of the report which was received shortly before the end of the year.

Pecos River watershed

Soil Conservation Service plans for revision of the Rio Puerco survey report were suspended in favor of early revision of the Pecos River survey. The R-3 representative was again detailed to the survey group at this station for approximately 4 months and assigned to the Soil Conservation Service survey crew to do the Forest Service portion of the survey revision. Basic data pertaining to national forests and associated lands were included in the survey report together with recommendations for works of improvement designed for flood control purposes. Preliminary draft of the report and appendix material was received just before the end of the year and review by R-3 and the Southwestern Station arranged.

Gila River watershed survey

Forest Service phases of the review of the upper Gila River survey report were handled by a representative of R-3 who was detailed to the survey party for a period of approximately 50 days. Basic data were checked and brought up to date and a proposed improvement program prepared but this material was developed only in preliminary form.

Survey of South Platte watershed

In midsummer it was learned that authorization and some funds had been made available for initiating a survey of the Forest Service portion of the South Platte, comprised of that part of the watershed above Greeley, Colo. Full assignment of personnel to other current surveys prevented any field work during the summer and fall of 1947. However, some time was spent in reviewing the preliminary examination report and especially in studying the recommendations therein for a hydrologic study including necessary installations on Bairs Creek, a tributary to the South Platte. Several conferences were held with members of the Rocky Mountain Station and representatives of the Washington office and it was finally decided to delete this study as a part of the survey procedure but to consider the recommendation as an evaluation phase of the improvement program in the survey recommendations.

Miscellaneous accomplishments

Four members of the survey staff spent a week or more assisting the Division of Watershed Management Research in a study of the relations of accelerated erosion to the alluvial deposits formed by Farmington and Davis Canyons in Davis County, Utah.

Two staff members, in company with representatives of the Rocky Mountain Station devoted 3 days to a reconnaissance survey of the Wind River Basin in Wyoming as a result of inquiry by the chairman of the Department of Interior, Missouri River Basin Field Committee for a study of the basin by representatives of all land management agencies concerned for the purpose of developing a program of watershed improvement and flood and sediment reduction. Later the Division Chief attended a 3-day conference and field study by Departments of Interior and Agriculture representatives at Riverton, Wyo., on the flood and sediment problems of the basin at which time plans were put into effect for a formal study of the problem and for the development of a program of remedial measures.

Present indications are that the flood control survey program in the Missouri River Basin by the Department of Agriculture will be materially accelerated and in this connection members of the Survey staff attended a 4-day conference of Forest Service and Soil Conservation Service personnel in December at Lincoln, Neb., for the purpose of considering plans for completing flood control surveys for all of this basin within the next 2 to 5 years.

The Division assisted R-2 and the Rocky Mountain Station in a special study of the Kannah Creek watershed which is the source of water for the city of Grand Junction, Colo. Flood Control Survey personnel made a brief study and analysis of the effect of roads and trails upon erosion and sedimentation. This included consideration of the need for engineering structures as an aid in reducing the flood and sediment damages which now occur.

Plans for 1948

Preparation, review, and revision of reports

Final drafts of appendix material for the Sevier Lake watershed survey report have been processed but it is expected that some rewriting and final typing of the report itself will need to be done as soon as review by the Washington office is completed.

First draft of the revised survey report for the Boise River (Idaho) watershed will be completed in early January while similar reports for the Cherry Creek (Colo.) and Fountain River (Colo.) watersheds will be completed in March. After preliminary review by the Washington office of the Forest Service these reports will be forwarded to regional offices of the Soil Conservation Service and the Forest Service for review and comment. After these reviews, second drafts of the reports and appendix material will be prepared which will include necessary changes in text and presentation. The reports will then be circulated to field offices of other interested Federal agencies for field clearance after which they will be submitted to Washington for final Forest Service consideration and action.

It is difficult to estimate the amount of time required for rewriting and processing as outlined above, as well as dates for completion since both will be governed by the length of time required for review. Project leaders will be assigned responsibility for necessary revision and this work will be given priority over other assignments.

Field clearance by the Forest Service for the Soil Conservation Service flood control survey reports on the Queen Creek, (Ariz.) and Pecos River (N. Mexico & Texas) will be completed during January.

The results of investigations by a representative of the Forest Service of the national forest portion of the upper Gila watershed (Ariz. & N. Mexico) will be transmitted to the Soil Conservation Service flood control survey group in late January or February for inclusion in a flood control survey report to be submitted by the Soil Conservation Service during 1948. It is expected that review by the Forest Service of preliminary drafts and later revisions of this report will be required during the spring and summer.

Wasatch Front survey

The Wasatch Front watershed survey will be continued with October 1, 1948 as an anticipated date for completion of the first draft of the report.

Winter and early spring months will be utilized for the collection, compilation, and analysis of data pertaining to flood damages, hydrology, and sedimentation. Flood damages to roads and those caused by roads were investigated and a proposed remedial program prepared during 1947 but other engineering phases of the survey remain to be studied. Most of this latter work will be done during the first quarter of the year but some portions may be delayed until snow recedes from the lower and middle elevations.

In the land use part of the survey there remain approximately 30 days of mapping of plant cover-erosion categories by a 2-man crew and about 6 weeks of detail mapping of plant cover-erosion conditions on sample watersheds by a 2-man crew. Nearly all of this work will need to be done at elevations above 7,000 feet and cannot be gotten under way until June 1-15 when roads are opened and snow cover melts. If available funds permit, completion of this phase of the survey will be expedited by employing student assistants in semiprofessional grades for compilation of data coincident with field mapping.

Current methodology for this phase of flood control surveys is being closely scrutinized for possible changes which will shorten completion time and reduce costs and manpower requirements.

South Platte watershed (Colo.)

A new flood control survey of the Forest Service portion of the South Platte River watershed, to begin during F. Y. 1948 has been authorized.

Examination of existing data was begun in 1947 and there were preliminary conferences with the Rocky Mountain Station and R-2 of the Forest Service on survey plans.

In February a work outline will be prepared and referred to the Soil Conservation Service for concurrence. Also during February it is planned to develop a plan and program for hydrological investigations consisting principally of infiltration tests. Early arrangements will be made with the Soil Conservation Service for the assignment of technicians to assist with the survey on the croplands of the watershed. It is estimated that this assistance will amount to about 16-man months.

Tentative arrangements have been made with the Rocky Mountain Station for facilities such as office space, furniture, car storage, etc. in conjunction with the station at Ft. Collins.

Because of weather conditions it is apparent that field work cannot begin before late May or June 1, but present planning is directed toward finishing all of the field work during 1948 with a probable submission of the report in June 1949. Critical elements of the plan appear to consist chiefly of infiltration tests since there is a distinct lack of such data which can be applied to this watershed. Tentative plans for early completion of this phase of the work include the use of additional infiltrometers of the North Fork type to supplement the large machine now available to the survey group.

Additional surveys

It is anticipated that additional watershed surveys will be initiated during 1948. Indications are that these will be within the Missouri Basin in accord with the present emphasis on early coverage by flood control surveys of the entire basin. Plans for this accelerated program have not yet progressed to the stage which permits statement of definite objectives for additional survey work during 1948, however, it is possible that this will consist of initiation of a survey of the North Platte watershed (Colo. and Wyo.) and assistance to the Soil Conservation Service on surveys by that agency on other watersheds of the Platte River and possibly in the Black Hills area of South Dakota.

RANGE ECONOMICS

A steadily increasing population in the Intermountain Region has resulted in more people demanding more intensive use of our wild lands. There are more users of domestic water, there is greater industrial use of water, and there are more recreationists. Simultaneously, there is a greater demand for food creating more of a demand for range forage for livestock and more water for irrigation of crops. There is also a greater need for timber for pulp and lumber.

Increased population pressure demands more improved and intensified management of wild lands and probably a shift in the importance of certain functions or uses of these lands. No land should be allowed to produce less than its maximum, sustained potential. Consequently, there is great need for economic and social evaluation of the various functions or uses of wild lands. There is also great need for such an evaluation of improved land management practices. Economic evaluation of the functions or uses of wild lands and of management practices on these lands are two of the major tasks of range economics research in the Intermountain Region.

There are three major reasons for economic evaluation of wild land management practices: First, to determine which practice, or practices, is the most profitable investment for private landowners. Second, society must know which practices are most productive in conservation of our resources so that public funds will be invested to best advantage. Third, to determine what portion of the cost of an improvement practice should be borne by the individual and what portion by society where such a practice is not profitable for the individual alone but is advantageous from the standpoint of both the individual and society.

Economic evaluation of the various uses of wild lands is fundamental to sound land management. Unless the most valuable functions of the land are known how is it possible to manage the land for the greatest or highest sustained income to society? Conservation or preservation of the land and vegetative resource in its pristine condition does not necessarily imply the most efficient use of the land. A false valuation may result in management of the land for a less valuable function or use. Valuation must also include both private and public value considerations. National forest lands are generally multiple use lands and thus there are several use values for each area of land. Proper evaluation of each use will enable land managers to emphasize management for the most valuable uses.

Obviously, land managers have not ignored the question of land use evaluation. However, present valuation methods lack uniformity and frequently result in land use valuations which are not comparable between two or more uses. Range economics research attempts to evaluate each function or use of national forest lands so that land managers can secure the maximum sustained income from the watershed, range forage, recreational, and timber producing functions of the land.

There has been a gradual shifting of the economic importance of certain land uses in the Intermountain Region. Originally, the region's agricultural economy was largely based on range livestock. The emphasis has now shifted more to crops and intensive forms of livestock and livestock products production. Much of the better spring-fall range has been turned over to crop production. Excessive use has destroyed the original productivity of other areas. Despite the reduction in range forage production, livestock numbers should be maintained so as to provide sufficient income for the many farm and ranch operators that are dependent on this form of production. The result of this action to date has been progressive deterioration of the existing range resource. There is great need for management practices which will permit the present level of livestock production to be maintained while at the same time preserving the vegetative resource on our wild lands.

Artificial reseeding of ranges has been shown to be possible on certain ranges. If economically feasible, it will be possible for stockmen to reseed their ranges and thereby maintain present livestock inventories. The important question of the economic feasibility of this practice needs analysis. Is it economical for stockmen to reseed their ranges? What reseeding methods are the most economical producers of range forage? If it is not economically feasible for stockmen to reseed certain ranges perhaps society has sufficient value at stake to assist the individual stockmen with reseeding.

The important range improvement practice of reseeding has been selected for economic appraisal by range economics research. A study of the economics of this practice has recently been initiated by this project. Preliminary results indicate that range reseeding is limited largely to stockmen with a surplus or abundance of range. Operators with a shortage of range apparently have been unable to reseed. A shortage of capital or the pressing need for range may be the cause of the latter type of individual being unable to reseed. Simultaneous with the study of the cost of and returns from range reseeding an analysis will be made of the range management problems associated with this practice. Solution of the economic feasibility of artificial range reseeding and other range improvement practices will assist in furthering the overall pattern of range-watershed conservation in the Intermountain Region.

FOREST MANAGEMENT RESEARCH

Post-logging Reproduction in the Ponderosa Pine Type

A question of concern among foresters and timber operators of central Idaho is the extent of restocking of reproduction after logging in the ponderosa pine type. Seedlings have an extremely difficult time establishing themselves, largely due to lack of soil moisture prompted by low annual and seasonal precipitation and other plant competition. Since it is known that sufficient viable seed is produced over a reasonable period of time provided that a suitably distributed volume of merchantable trees is left after cutting, the question arises as to what condition of stocking (seedlings and saplings per acre) and distribution of them may be expected at various periods of time after cutting.

Casual observation would lead one to believe, that, given enough time and exclusion of fire, cut-over areas in central Idaho, both public and private, support good stands of second growth reasonably well distributed over the ground. To determine accurately the extent of this restocking and distribution was one of the main objects of the 1932 cut-over study which dealt with public and private land logged from 1906-22. During the past year some progress was made in the analysis of these data which show that:

a. Northern aspects generally support more reproduction than all other aspects with ridge aspects running a close second.

b. Creek bottoms support less reproduction than all other aspects with south aspects running only slightly higher.

c. The area logged longest ago (1906) supports markedly more post-logging reproduction than the other areas showing that time is required for seed years and favorable growing seasons to occur and produce good results. This area, from the reproduction distribution standpoint is 80 percent stocked in the ponderosa pine type.

d. In all areas, there is a higher number of seedlings per acre in the Douglasfir type than in the ponderosa pine type. Furthermore, there are more Douglasfir seedlings per acre in the Douglasfir type than ponderosa pine seedlings in the ponderosa pine type.

e. None of the areas examined is less than 52 percent stocked except the one area of private land which was 46 percent stocked and from which 98 percent of the volume had been removed.

f. There is relatively little post-logging reproduction of both ponderosa pine and Douglasfir during the first 10 years after logging.

These preliminary results indicate and stress the importance of leaving adequate (approximately one tree 18 inches diameter breast high or larger per acre) ponderosa pine seed trees to insure sufficient seed for the occasional year when a favorable growing season occurs. The other chief object of this study was to learn the effect of cutting on the mortality, growth, and stand structure of residual stands. After considerable inspection and examination of the data and previous analysis, deliberation, and consultation with mensurationists it was decided to postpone completion of this phase of the study.

Other activities

A start has been made on formulating a problem analysis aimed at developing a forest research program for the Intermountain Region.

Visits were made to Fort Valley Experimental Forest, Flagstaff, Ariz., of the Southwest Forest and Range Experiment Station; the Forest Genetics Institute, Placerville, Calif., the Feather River Branch Station, Quincy, Calif., and Black's Mountain Experimental Forest, Susanville, Calif., of the California Forest and Range Experiment Station; and Pringle Falls Experimental Forest, Lapine, Ore., of the Pacific Northwest Forest and Range Experiment Station. The purpose of these visits to other work centers, all of which are investigating different phases of ponderosa pine management, was to examine the research program of other workers in this species, to learn the forest management problems of other regions and to learn, in a general way at least the results of past studies and the trends of current ones.

Visits were also made to private and national forest land in Utah to inspect aspen stands and to learn the degree of utilization of this species. From the examination of many stands and cutting and mill operations it is evident that aspen is a silviculturally adaptable species and that greater use could be made of this species than is being done at present. Relatively little silvical and still less silvicultural knowledge is available for this species and hence it would seem worthwhile to learn more about it under conditions of commercial cutting practice which is currently accessible.

In order to learn national forest policies of central Idaho a number of trips were made on the Boise National Forest with Administration personnel to observe timber marking and conditions of forage. Active assistance was given to Administration on an experimental forest seeding project on the High Valley Ranger district of the Boise National Forest.

Plans for 1948

Complete reproduction and quadrat stocking phase of cut-over study. Further development of problem analysis. Continue analysis of file data on ponderosa pine research studies now requiring attention.

RI - INT
SOIL STABILIZATION
Watershed

February 1, 1948

STABILIZATION OF GRANITIC MOUNTAIN SOILS - BOISE - R.C.

1. Field division: Watershed management and protection

2. Work Project: Soil stabilization

3. Line Project: Watersheds

4. Purpose: Determine extent and how forest range resources on loose granitic soils can be utilized without causing accelerated erosion and develop methods of stabilizing eroding areas.

5. Review of past work: Surveys revealed serious erosion-sedimentation problem on Boise River watershed. High intensity summer rains and site disturbance by grazing, fire, logging, roads, and mining found to be causes of soil displacement; snowmelt runoff a major carrier of sediments in channels. Infiltrometer studies showed erosion increased with slope steepness and trampling and that restoration of perennial bunchgrass essential for soil stability on grassland range, but studies suspended before specific requirements for protection were determined.

6. Accomplishments during past year: Developed and calibrated three units of improved Type F infiltrometers to speed up determination of protection requirements. New units cut operating costs (manpower, water and transpiration) about 50 percent. Found in exploratory test on 32 grassland sites protected from grazing for 18 years that (1) ground surface cover (basal area of plants plus litter) best single index of runoff and soil stability, with soil depth and pore space major factors causing error; (2) above ground density of vegetation relatively unimportant from standpoint of runoff, but of major importance in controlling erosion, especially on poor sites; and (3) a total ground cover in excess of 90 percent required to keep soil losses to less than 200 pounds per acre when subjected to a 1.80-inch storm at about 3.60-inch per hour intensity. Extensive inspection revealed continued accelerated erosion and uncertainty regarding the specific requirements for watershed protection particularly on (1) deteriorated and reseeded spring-fall grassland, (2) Stipa-lupine summer range, (3) ponderosa pine logging chance, and (4) roads.

7. Plans for next year: Complete analysis and publish reports on (a) 1947 infiltrometer study and (b) description of new infiltrometer. Initiate detailed infiltrometer study to determine protection requirements on (a) spring-fall range and (b) summer range.

8. Date of completion: Indefinite

9. Assignment: Paul E. Packer and ____________.

RI - INT
SOIL STABILIZATION
Watershed

February 1, 1948

STABILIZATION OF VARIABLE HIGH PLATEAU SOILS - GREAT BASIN R.C.

1. Field division: Watershed management and protection

2. Work project: Soil stabilization

3. Line project: Watershed

4. Purpose: Determine extent and how forest and range resources on variable high plateau soils in central Utah can be utilized without causing accelerated erosion and develop methods of stabilizing eroding areas,

5. Review of past work: Extensive accelerated erosion observed to be caused by overgrazing. Situation especially serious on headwater slopes. Since 1916 measurements of runoff and soil losses from 10-acre Area A and B, watersheds show (1) surface runoff and erosion has been substantially increased on herbaceous range with heavy limestone soil and where plant cover density was reduced below 40 percent and the soil disturbed by trampling; (2) 30 years protection from grazing and attendant increase in average plant cover density from 16 to 50 percent reduced surface runoff and soil loss but has not affected satisfactory control.

6. Accomplishment during past year: Infiltrometer study initiated on A-B areas to determine factors responsible for runoff and erosion. All of 10 sites in Area B with plant and litter cover reduced to 20 percent by over-grazing, yielded about 90 percent runoff and from 1,000 to 9,000 grams of soil per plot regardless of major differences in soil depth and rock pavement. Comparable sites in Area A yielded similar amounts of runoff and soil whereas sites with plant and litter cover densities in excess of 60 percent yielded about 15 percent runoff and about 70 grams of soil per plot. These confirm observations that effective stabilization of these areas requires more than 60 percent plant and litter density on all slopes. Trampled soils were found to have about 50 percent less air space available for storage of water than untrampled sites. Reduction of storage capacity by trampling is no doubt a contributing factor to increased runoff and erosion on overgrazed range.

7. Plans for next year: Complete infiltrometer paper. Continue infiltrometer study of A-B areas, install more sensitive weirs and make preliminary analysis of all A-B data with view toward publication next year. Initiate study of soil stabilization tests in cooperation with reseeding project.

8. Date of completion: Indefinite

9. Assignment: Howard Lull and ____________________

RI - INT
SOIL STABILIZATION
Watersheds

February 1, 1948

STABILIZATION OF VARIABLE MOUNTAIN SOILS - WASATCH R.C.

1. Field division: Watershed management and protection

2. Work project: Soil stabilization

3. Line project: Watersheds

4. Purpose: Determine extent and how forest and range resources on variable mountain soils in northern Utah can be utilized without causing accelerated erosion and develop methods of stabilizing eroding areas.

5. Review of past work: Overgrazed and burned portions of herbaceous, brush, and woodland sites in headwaters of steep canyons of Wasatch Mountains are known to be eroding rapidly; some are source of destructive mud-rock floods. Soil losses during individual storms in period 1934-46 found to range from zero on well covered aspen sites to 192 cu. ft. per acre on deteriorated herbaceous sites. Examination of 2,000 permanently located study plots in 1936-37 revealed up to 70 percent less in organic matter content, nitrogen and moisture equivalent on eroded soils. These plots also served as tentative index of cover conditions required for protection.

6. Accomplishments during past year: Erosion plots were treated to determine effects of denudation and of artificial recovery by mulching and seeding. One rain of moderately high 5-minute intensity caused loss of 140 cu. ft. of soil per acre from denuded aspen site which previously had lost no soil in 12 years; heavy loss (60 cu. ft. 1 acre) also from denuded herbaceous site. No measurable soil loss from aspen sites with both high- and understory cover or with aspen removed and understory remaining; or from herbaceous sites with natural encroachment of young aspen and herbaceous cover, or with mulch and seedling stand of grass. That yield of sediment from the steep canyon along the Wasatch Mountains can be increased 1,000-fold is clearly indicated in results of a study of recent mud-rock flood deposits. Morris Canyon, a nonflooding tributary of Farmington Canyon, has yielded about .0004 acre foot of sediment per square mile per year during the past 11 years. Farmington Canyon has yielded 588 acre feet of sediment since it produced the first major mud-rock flood of historic time in 1923. Bairs Canyon since flooding in 1912, has yielded about 130 acre-feet of sediment. These deposits respectively, are equivalent to annual sedimentation rates of about 2.5 and 1.0 acre feet per square mile.

7. Plans for next year: Develop report on watershed protection requirements for herbaceous, shrub, and woodland sites based on analysis and some field checking of 2,000 observation plots and of related hydrologic data. Continue operation of erosion plots to further check effects of mulching, etc. on stability.

8. Date of completion: Indefinite

9. Assignment: A. R. Croft, R. B. Marston, and A. Blain

RI - INT
STREAM FLOW
Herbaceous cover

February 1, 1948

INFLUENCE OF HERBACEOUS COVER ON STREAM FLOW - BOISE R.C.

1. Field division: Watershed management and protection

2. Work project: Stream flow

3. Line project: Herbaceous cover

4. Purpose: To determine for bunchgrass-granitic soil range lands of southern Idaho, the management practice acquired for obtaining plant and soil conditions that will yield maximum quantities of usable stream flow.

5. Review of past work: In 1935, two 10-acre watersheds and in 1937 three 200-acre watersheds were equipped with stream gaging stations. Operation of these units was suspended in 1942.

6. Accomplishment during past year: None

7. Plans for next year: Keep project in suspension

8. Date of completion: Indefinite

9. Assignment: Paul E. Packer and ____________________

RI - INT
STREAM FLOW
Herbaceous Cover

February 1, 1948

INFLUENCE OF HERBACEOUS COVER ON STREAM FLOW - GREAT BASIN R.C.

1. Field division: Watershed management and protection
2. Work project: Stream flow
3. Line project: Herbaceous cover
4. Purpose: To determine for watersheds with herbaceous cover on the Wasatch Plateau, the relation of stream flow phenomena to grazing management practices and to watershed improvement measures.
5. Review of past work: About 95 percent of perennial stream flow known to be derived from winter precipitation, particularly snow, and balance largely destructive overland flow during summer rains. Flumes were installed on several headwater subbasins in headwaters of Ephraim Creek, also at Bluebell Bridge and Power Plant with view of evaluating effects of watershed improvement measures on stream flow.
6. Accomplishments during past year: Cleaned and repaired all stream gaging stations. Revised rating curves from current meter readings. Completed calculations of discharges for period of record (Approx. 1940-47) for Ephraim Power Plant, East Portal Ephraim Tunnel, Dave Madsen Ditch, and John August Ditch. Prepared plans for improvement of area A and B gaging stations so as to obtain detailed unit storm records.
7. Plans for next year: Complete calculation and compilation of stream flow records. Install new weirs in A and B tank. Continue stream flow records on A and B, Left Hand Fork, Alpine Cattle Pasture, Bluebell, Power Plant, and Transmountain Diversion.
8. Date of completion: Indefinite
9. Assignment: Howard Lull and ____________________.

RI - INT
STREAM FLOW
Woodland

February 1, 1948

INFLUENCE OF WOODLAND COVER ON STREAM FLOW - WASATCH R.C.

1. Field division: Watershed management and protection

2. Work project: Stream flow

3. Line project: Woodland cover

4. Purpose: To determine for watersheds with woodland (mixed trees, shrub, and grass cover) on steep watersheds in northern Utah the management practices that will insure the most valuable yield of water.

5. Review of past work: Intensive studies of summer storm mud-rock flood behavior initiated on experimental watersheds in 1933. Contour trench system developed and applied to prevent recurrence of destructive floods. System proved effective in preventing floods during high intensity storms in 1936 and again in 1945.

6. Accomplishments during past year: Adequately treated experimental watersheds again prevented mud-rock flood during 1.00-inch summer storm that carried debris flows in three inadequately treated subbasins of Farmington Canyon and in adjacent Bairs Canyon. Source of these floods was traced to untrenched and inadequately trenched areas and to faulty road drainage. Chute-type flume passed the debris flow safely giving good indication of head and duration of flood. Venturi-trapezoidal flumes failed by plugging with gravel and heavy boulders. Analysis shows summer flood control contingent upon coping with 5-minute rainfall intensities up to nearly 9.00 inches per hour. Of 153 rains in July and August between 1936 and 1937 only 9 produced runoff from "barren" plots. Rainfall of between 1/4 and 1/2 inch will produce runoff from poorly covered sites if rates are greater than 2 inches per hour for 5 minutes. The three most effective storms of record were between 1.00 and 1.25 inches in volume and produced rates in excess of 4.00 inches per hour for 5 minutes. Prepared publications on results of flood control in Davis County as part of know your watershed program.

7. Plans for next year: Publish reports on (a) Bairs Creek flood and (b) summer storm characteristics. Utilize accumulated data from this and Soil Stabilization project to develop technical bulletin on watershed protection requirements of woodland watersheds.

8. Date of completion: Indefinite

9. Assignment: A. R. Croft, R. B. Marston and Blain.

RI - INT
WATER UTILIZATION
Herbaceous Cover

February 1, 1948

WATER UTILIZATION BY HERBACEOUS COVER - BOISE R. C.

1. Field division: Watershed management and protection

2. Work project: Water utilization

3. Line project: Herbaceous cover

4. Purpose: To determine kind of cover required for minimum evapo-transpiration losses.

5. Review of past work: Found average annual water loss from 4-foot deep lysimeters at Bannock substation to be 12.08 inches or 50 percent of annual precipitation. No significant difference in loss between climax, subclimax, and annual weed cover. Shifted approach to weekly determinations of soil moisture on annual weed and densely covered (reseeded) bunchgrass sites at Arrowrock substation. Both sites became about equally dry by end of summer. Lack of volumetric measurements precluded calculation of water loss but equal dryness suggested recovery of deteriorated range for soil stability purposes should not decrease water yields.

6. Accomplishments during past year: Made volume weight study of Arrowrock soil moisture sampling sites. Assuming volume weight values same as in 1941, when soil moisture was measured to a depth of 30 inches, calculations show bunchgrass and annual weed sites held 3.37 and 3.36 inches of water respectively at start of growing season and held 4.36 and 4.49 inches at end of season. With season rainfall added, these differences show that evapo-transpiration losses were about 6.45 inches on the densely covered bunchgrass site and 6.31 inches on the annual weed site.

7. Plans for next year: Complete analysis including calculation of water volumes for the 1942 season when soil moisture was measured to a depth of 6 feet and publish a report on the Arrowrock evapo-transpiration study.

8. Date of completion: Indefinite

9. Assignment: Paul E. Packer and ________________.

RI - INT
WATERSHED UTILIZATION
Herbaceous Cover
February 1, 1948

WATERSHED UTILIZATION BY HERBACEOUS COVER - GREAT BASIN R.C.

1. Field division: Watershed management and protection

2. Work project: Water utilization

3. Line project: Herbaceous cover

4. Purpose: To determine kind of cover required for minimizing evapo-transpiration losses from high plateau watersheds.

5. Review of past work: Duplicate soil moisture sampling pits were established on a herbaceous site in the head of Ephraim Canyon in 1941. Measurements were abandoned during the war.

6. Accomplishments during the past year: None

7. Plans for next year: None

8. Date of completion: Indefinite

9. Assignment: Howard Lull and ______________________.

RI - INT
WATER UTILIZATION
Forest (Woodland)

February 1, 1948

WATER UTILIZATION BY WOODLAND COVER - WASATCH R. C.

1. Field division: Watershed management and protection

2. Work project: Water utilization

3. Line project: Forest (woodland)

4. Purpose: To determine kind of cover required for minimizing evapo-transpiration losses from woodland watersheds.

5. Review of past work: Year round measurements of soil moisture to depths of 6 feet at an elevation of 7,000 feet show evapo-transpiration loss on a south aspect brush site of about 13.4 inches and of about 14.4 inches on a north aspect aspen site. These losses represent slightly less than 50 percent of the annual precipitation on these sites (33 inches).

6. Accomplishments during past year: Study extended to aspen and herbaceous sites at 8,300 elevation head of Parrish Creek. Soil moisture determinations revealed aspen site with undercover of herbs and litter, aspen site with aspen removed, and aspen site with all cover and litter removed held essentially same amount of water (15-18 inches) at start of growing season. Water content at end of growing season showed losses to be about 20 inches from untreated aspen site, 15 inches from site on which aspen only was removed, and 7.5 inches from denuded site. Complete denudation not feasible because of flood and erosion hazard. The 5-inch greater consumptive loss on untreated aspen than on herbaceous site is a first rough measure following treatment and need further checking. It suggests aspen harvesting (for pulp, excelsior, etc.) but leaving herbaceous understory, would increase water yield by 5 inches as well as provide better forage and equally effective protection against summer floods and erosion.

7. Plans for next year: Continue and refine soil moisture study in aspen, herbaceous, and denuded sites.

8. Date of completion: Indefinite

9. Assignment: A. R. Croft, R. B. Marston, and A. Blain.

RI - INT
CLIMATE
Forest

February 1, 1948

CLIMATIC EFFECTS OF FOREST COVER - BOISE R. C.

1. Field division: Watershed management and protection

2. Work project: Climate

3. Line project: Forest

4. Purpose: To determine cover conditions required for increasing accumulation and delay of snowmelt.

5. Review of past work: Exploratory studies indicated harvesting of ponderosa pine favored accumulation of snow and delayed snow-melting. More detailed records of snow accumulation and melting obtained over two winters but data never analyzed.

6. Accomplishments during the past year: None

7. Plans for next year: Analyze accumulated data and report results.

8. Date of completion: Indefinite

9. Assignment: Paul E. Packer and ____________________

RI - INT
CLIMATE
Herbaceous Cover

February 1, 1948

CLIMATE EFFECTS OF HERBACEOUS COVER - GREAT BASIN R. C.

1. Field division: Watershed management and protection

2. Work project: Climate

3. Line project: Herbaceous cover

4. Purpose: To determine cover conditions required for maximum accumulation of snow and prolonged snowmelt on high plateaus of central Utah.

5. Review of past work: Snowmelt rates found to average about .70 inch per day (in 6 hours) with maximum rate of 2.00 inches. Full shade reduced heavily melting rates during days of rapid melt by about 50 percent.

6. Accomplishments during past year: Exploratory studies indicated aspen cover has little effect on either snow accumulation or rate of snowmelt. Snowmelt was one-third less rapid in conifer than in aspen sites. Conifer clumps on windswept slopes produced drifts with two to three times the depth of snow than on aspen slopes. These drifts remained from 1 to 3 weeks longer than general snow mantle. Installed three drift fences to determine feasibility of inducing snow drifting as means of increasing snow accumulation and delaying snowmelt and of lowering spring peaks and increasing summer stream flow.

7. Plan for next year: Continue snow accumulation and melting study.

8. Date of completion: Indefinite

9. Assignment: Howard Lull and ________________.

RR - INT
MANAGEMENT
Summer Range

February 1, 1948

SUMMER RANGE

1. Field division: Range research

2. Work project: Grazing management

3. Line project: Summer range

4. Purpose: To develop practices for grazing mountain range lands so as to restore and maintain soil stability and desirable forage.

5. Review of past work: Early research on plant succession and seasonal development on the Wasatch Plateau is reported in USDA Buls. 791 (1919) and 1405 (1926). USDA Tech. Bul. 686 (1939) treats seasonal plant development and grazing periods in greater detail. Relations between vegetal cover, runoff and erosion are described in USDA Tech. Bul. 220 (1931). Data on seed germination of important range species are reported in Bot. Gaz. 98:243-269 (1936). Climatic characteristics are summarized in Monthly Weather Rev. 65:291-301 (1937). Seasonal march of carbohydrates in important forage plants in relation to time of grazing is described in USDA Tech. Buls. 598 (1938) and 818 (1942). A resume of indicators of range-watershed condition and trend was published as Intermountain Sta. Res. Paper No. 6 (1945). This material has undergone extensive revision, and is currently in process of further revision for Departmental publication. During the past 10 years permanent plot data have been systematically collected and observations made to reconstruct the character of the original vegetation of the subalpine zone of the Wasatch Plateau and to describe changes it has undergone since settlement.

6. Accomplishments during past year: Results of the last 10 years' effort and 34 years of plot records were summarized in a manuscript, "Subalpine Vegetation of the Wasatch Plateau, Utah." While there are several distinct seres, the one culminating in the mixed upland-herb association is most important from the standpoint of range-watershed management. This appears to have been originally a mixed cover dominated by tall, mesic herbs, grasses, and sedges. Early overgrazing denuded the range, causing accelerated erosion and invasion by annual weeds which, under less intensive grazing, have been succeeded by various grasses, herbs, and shrubs, all distinctly more xeric than those characterizing the original vegetation. Vegetation on sheep range tends toward xeric grasses, on cattle range toward xeric herbs. Accelerated erosion is still the rule over most of the subalpine zone.

7. Plans for next year: Complete observations on certain phases of normal soil-plant succession on Wasatch Plateau and revise manuscript for publication; continue observations begun in 1942 on subalpine zone of Aquarius Plateau.

8. Date of completion: Indefinite

9. Assignment: Lincoln Ellison

RR-INT
MANAGEMENT
Utilization Standards

February 1, 1948

RANGE UTILIZATION

1. Field division: Range research

2. Work project: Grazing management

3. Line project: Utilization standards

4. Purpose: Determine standards of utilization on mountain rangelands to keep soils in place and to maintain or restore palatable vegetation.

5. Review of past work: Utilization standards have been approached by considering effects of grazing both on individual plants and on the plant community. Under the first approach this project studied methodology, and in 1941 set up an intensive investigation of effects of grazing intensity and site on 1,900 staked plants of two species of range grasses. Sampson placed emphasis on the plant community when he described successional stages of vegetation as criteria of condition. Following this line of thought, a condition study of the aspen type was begun in 1946.

6. Accomplishments during past year: Preliminary analysis of data from the 1,900 staked plants gave as tentative conclusions: (1) Degree of utilization of slender wheatgrass and mountain brome is least on plants of largest size as measured by height, weight, and presence of flower stalks. (2) Degree of utilization of these grasses is least on areas supporting either most grass or most dandelion. Judging from limited natural areas and a few old quadrats, the natural aspen understory community is generally a mesic one of tall herbs. It is highly variable, reflecting in species composition and herbage production not only intensity of grazing use but also habitat factors, successional stages of the overstory, and species composition of bordering plant types. Most of the stands found have more grass, more low, unpalatable weeds, or less brush than the "natural" ones. Increasing intensity of grazing produces progressively more xerophytic stands and cuts herbage production from a maximum of 2 tons to a few hundred pounds per acre.

7. Plans for next year: (1) Complete analysis of the plant vigor and site data. (2) Continue aspen condition study and prepare a preliminary scheme of condition class indicators.

8. Date of completion: (1) Early in 1948; (2) Indefinite

9. Assignment: Jack Major

February 1, 1948

BIG GAME-LIVESTOCK RANGE

1. Field division: Range research

2. Work project: Grazing management

3. Line project: Big game-livestock range

4. Purpose: To gather facts and develop principles and concepts which will form the basis for management of range lands for production of big game and livestock and for conservation of other values.

5. Review of past work: Steady increase in big game, with overbrowsing on many ranges, has made the controversial question of conflict between big game and livestock increasingly acute. Cooperative work with State agencies within a fenced deer range, started in 1939, was discontinued in 1942 when fire destroyed the fencing. In 1946 a cooperative organization including Forest Service, Utah State Fish and Game Commission, Utah State Agricultural College, U. S. Fish and Wildlife Service, and Bureau of Land Management was formed to carry out coordinated research on big game-livestock ranges.

6. Accomplishments during past year: Problem analysis has been carried forward. Exploratory studies yield the following tentative results: (a) On Oak Creek unit, Fishlake N. F., heavy use by deer occurs in some places inaccessible to cattle but on all areas used heavily by cattle there is also heavy use by deer. (b) Although food habits of deer and cattle differ considerably, on several national forests a few plants are highly preferred by both. (c) Deer use rough and timbered areas not grazed by sheep, but they prefer the same feedgrounds where choice forage occurs. (d) Diets of deer and sheep are strikingly similar on the spring and early summer range studied. Sheep eat much more grass than deer in late summer, but species of shrubs and forbs preferred by deer at this season are also readily used by sheep. (e) Deer problem areas are widespread in Utah. Of the 52 major deer units in the state, only 12 are without known problem areas; 38 have winter range problem areas; and 2 have summer range problem areas. Fifteen of the 38 units with winter problem areas also have summer problem areas.

7. Plans for next year: Continue present exploratory studies. Complete problem analysis and prepare long-time research program. Publish, with cooperating agencies, an illustrated leaflet on game range conditions in Utah.

8. Date of completion: Indefinite

9. Assignment: Odell Julander and Justin G. Smith

February 1, 1948

SPRING-FALL RANGE

1. Field division: Range research

2. Work project: Grazing management

3. Line project: Spring-fall range

4. Purpose: To determine for spring-fall range, effects of different methods of grazing management, and of different seasons and intensities of grazing, upon individual plant species, animal and forage production, and soil.

5. Review of past work: Investigations begun in 1923 continue to show that a rotation system of grazing is important on sagebrush-grass ranges. Grazing intensity study was revised in 1941 and rates of stocking increased to 14, 18, and 22 sheep days per acre in spring and similar stocking in fall. Indicators of downward trend began to show up on heavily stocked ranges after only 3 years. Palatable perennial herbs and grasses showed decreased vigor--shorter stems, smaller leaves, fewer flower stalks, and smaller flowers. A greater number of annuals of larger size appeared on heavily stocked ranges as compared to those less heavily stocked. Numerous young sagebrush plants have become established in openings between mature sagebrush bushes. Portions of perennial herbs and bunchgrasses have died out and those remaining on sloping sites have become excessively pedestalled.

6. Accomplishments during past year: Observations in 1947 show that yields of important perennial grasses on heavily stocked range have declined 43 percent since 1941 in relation to those on adjacent lightly stocked range. Important herbs decreased 27 percent, and browse increased 12 percent, due mainly to increased production of sagebrush. Weights of ewes and lambs grazed on heavily, moderately, and lightly stocked pastures showed significant differences in the spring of 1947 for the first time. Ewes and lambs, taken as a unit, gained 35.5 pounds on lightly stocked range, 31.0 pounds on moderately stocked range, but only 22.1 pounds on heavily stocked range.

7. Plans for next year: Continue pasture grazing studies through 1948 to complete second rotation cycle. Resurvey Fremont County experimental burn to determine changes on sagebrush-grass ranges 15 years after burning. Continue problem analysis of Upper Snake River drainage.

8. Date of completion: Indefinite

9. Assignment: Clark E. Holscher

RR - INT
MANAGEMENT
Winter Range

February 1, 1948

WINTER RANGE

1. Field division: Range research

2. Work project: Grazing management

3. Line project: Winter range

4. Purpose: To develop range management methods which will permit the rehabilitation of denuded areas, provide for maximum forage yield and promote the best use of winter range.

5. Review of past work: In 10 years of managed grazing at the Desert Station, plant cover has increased from 50 to 150 percent, plant vigor of many of the better forage species on moderately grazed range has increased so that herbage produced per plant is from 4 to 8 times greater than on adjacent heavily grazed areas. Seedling production is almost equal on moderately and heavily grazed range, but survival is many times greater on moderately grazed range. Moderately grazed range shows approximately the same improvement in plant vigor and increased herbage production as areas totally protected. Over a period of 6 years ewes on moderately grazed winter range maintained 8 pounds better flesh, produced .95 pound more wool, and suffered 5 percent less death loss than ewes on heavily grazed range. Herbage yield fluctuates markedly with precipitation. In 1943 when precipitation (Oct. to Sept.) was 4.4 inches, herbage yield was 75 pounds per acre air-dry, while in 1938 when precipitation was 8.8 inches, herbage yield averaged 264 pounds.

6. Accomplishments during past year: Revision and amplification of the desert management manuscript, based upon studies begun in 1932, has been the chief effort. One drawback in the records is a progressive decline in forage production, on managed as well as overgrazed range, because of a decline in precipitation. With the advantage of exceptionally high precipitation preceding the past growing season, an additional inventory was made of many pastures and enclosures. The results of this examination are being compiled and analyzed.

7. Plans for next year: Complete revision of desert management manuscript.

8. Date of completion: Indefinite

9. Assignment: Selar S. Hutchings

RR - INT
ARTIFICIAL REVEGETATION
Species Adaptability

February 1, 1948

SPECIES ADAPTABILITY STUDIES

1. Field division: Range research

2. Work project: Artificial revegetation

3. Line project: Suitability of plant species for artificial revegetation.

4. Purpose: To determine which forage species, whether native, introduced, or produced by plant breeding, are best adapted to the various problem areas of the Intermountain region.

5. Review of past work: Since 1936 seed from 400 species has been planted on weed-free dryland nurseries at eight climatologically different locations in the region. In 1940 tentative recommendations were compiled on adaptability of 25 species which had survived tests simulating range conditions; 5 most promising species were planted for seed production. In 1944 general nursery work was reduced from eight to four and concentrated at the Great Basin Branch Station in Ephraim Canyon, Manti National Forest. Orchardgrass (Dactylis glomerata) has been dtermined to be especially adapted to seeding under aspen, oakbrush, and scrub maple. Four new species, Agropyron intermedium, A. trichophorum, A. elongatum, and Elymus junceus have for 4 years given promise of high yields and a longer grazing season than crested wheatgrass at lower elevations. Approximately 100 strains of standard species have been collected since 1943 and subjected to nursery trial.

6. Accomplishments during past year: Determination of the value of the four promising new species is underway on range plot tests and a seeding made of two larger pilot plantings. Plots now seeded will in a large measure establish suitability to elevational, vegetational, and precipitation zones and indicate the probable length of grazing season. Seeds of these species and other desirables are being grown by cooperating farmers with satisfactory results as to yield and quality. About 20 new strains obtained by selection and plant breeding were added to a previous good collection. Many strains in the nursery have given higher yields than the stock species. Observations on palatability were continued.

7. Plans for next year: Continue nursery trials and field checks of promising species and seed production tests. Determine herbage yields of species surviving field tests and initiate controlled grazing tests on reseeded areas. Cooperate in growing seeds of valuable new species.

8. Date of completion: Indefinite

9. Assignments: A. Perry Plummer, George Stewart, Richard M. Hurd, John Fenley, and J. P. Blaisdell.

February 1, 1948

ARTIFICIAL REVEGETATION METHODS

1. Field division: Range research

2. Work project: Artificial revegetation

3. Line project: Methods: time, depth, culture, practicability, and cost of planting.

4. Purpose: To determine the most practical time and methods of planting and subsequent treatment in the revegetation of depleted ranges.

5. Review of past work: Tests show that most effective seeding can be accomplished by fall sowing with a drill on brush-and rock-free sites, from which brush has been removed by fire or by the wheatland plow, by disking and harrowing on loose soils, and by deep furrow lister drilling on compact soils where weed competition must be reduced. Seed may, under favorable circumstances, be broadcast at the time of wheatland plowing. Covering seed by trampling and broadcasting on snow are unreliable. Only species adapted to climatic and site conditions are recommended.

6. Accomplishments during the past year: Burning in early summer was found to reduce cheatgrass sufficiently to permit drilling that fall without further treatment. Other methods of handling cheatgrass were compiled and a report prepared. The Australian stump-jump plow was found to be more efficient for sagebrush removal than any other machine tested. An equipment school was held for reseeding foremen of Utah forests; an analysis of results of brush removal made. Equipment committee meetings were held. Equipment Laboratory is building 6 plows of an improved type which combines good features of wheatland and stump-jump plows. All breakable parts are to be greatly strengthened. In the subalpine zone studies for control of tarweed, Wyethia, and dandelion were started or enlarged.

7. Plans for next year: Equipment trials and studies will be continued; also methods of handling cheatgrass, tarweed, Wyethia, and dandelion will be conducted more vigorously. Studies on seeding on loose granitic mountainous lands in Idaho are to be enlarged. More data on airplane seeding will be gathered. The improved plow built by the Equipment Laboratory will be tested. Data on effects of spraying to control brush in reseeded areas will be gathered and compiled.

8. Date of completion: Indefinite

9. Assignment: R. M. Hurd, George Stewart, Perry Plummer, John Fenley, and Clark Holscher.

RR - INT
ARTIFICIAL REVEGETATION
Site Factors

February 1, 1948

SITE FACTOR STUDIES

1. Field division: Range research

2. Work project: Artificial revegetation

3. Line project: Site factors: soils, climate, altitude, and other factors in relation to growth requirements of species used in artificial revegetation.

4. Purpose: To determine the effect of site factors on the growth and ultimate forage production of species used in artificial revegetation.

5. Review of past work: Competition for soil moisture from established dominants such as *Artemisia tridentata*, *Bromus tectorum*, and *Chrysothamnus* spp. is a frequent cause of failure of plantings made in these vegetative types, and a cause of trouble in subsequent management. Failure of artificial reseeding with *Oryzopsis hymenoides* has been found to be attributable also to delayed germination, considerably ameliorated in a few species by scarification and acid treatment of seeds. Retarded development due to cold temperatures and deficient precipitation has been serious in some seasons. Competition from *Artemisia* and *Bromus tectorum* with reseeded species has been studied and methods, mechanical and burning, recommended to overcome. Reseeded areas have in some cases been invaded by *Artemisia* and *Chrysothamnus* and these have been found to reduce the yield notably. Removal of mountain brush was found very difficult by mechanical means; fire was comparatively effective and low in cost. Found broadcasting seeds under aspen, maple, and oakbrush gave good results but took more time to develop stands; in fall of 1945 broadcast by airplane 1,300 acres of depleted aspen and oakbrush range; good stands developing, in most parts, but some nearly bare areas are found.

6. Accomplishments during past year: Data gathered from studies of methods of seeding in cheatgrass, mountain brush, by airplane under aspen and oakbrush; data were also gathered as to effect of burning as a means of removing sagebrush, cheatgrass, and mountain brush preparatory to reseeding. Initiated several studies on mountain land as to best method of removing competition of tarweed, dandelion, and Wyethia. Strengthened studies of removing competition and methods of seeding on loose granitic soils in Idaho. Began preliminary studies of methods of removing competition and seeding on salt-desert shrub winter ranges, and spray control of sagebrush and rabbitbrush on reseeded ranges.

7. Plans for next year: Continue study of controlling competition in cheatgrass, mountain brush, and desert brush. Prosecute studies on methods of seeding loose granitic soils in Idaho and of handling airplane seedings and seeded stands. Follow up preliminary work on spray control of sagebrush and rabbitbrush on reseeded range lands. Cooperate on modification of machinery more suitable for range work than present models.

8. Date of completion: Indefinite

9. Assignment: A. Perry Plummer, R. M. Hurd, John Fenley, and George Stewart.

RR - INT
ARTIFICIAL REVEGETATION
Plant Breeding February 1, 1948

SELECTION AND HYBRIDIZATION STUDIES

1. *Field division:* Range research

2. *Work project:* Artificial revegetation

3. *Line project:* Plant breeding: selection and hybridization (conducted in cooperation with the Bureau of Plant Industry and the Utah State Agricultural Experiment Station, the Bureau of Plant Industry acting as leader and prosecuting the detailed work).

4. *Purpose:* To produce improved strains of range plants by selection. To determine the pollen production and quality, and pollination and seeding habits of range plants as a basis for hybridization studies; and to produce improved strains of range plants by hybridization.

5. *Review of past work:* Several strains of eight species commonly used in range reseeding were planted at several localities between 1939 and 1946. Seed from species showing notable variation were collected and planted at the Great Basin Branch Station for further observation. Selected strains of *Bromus inermis*, *Agropyron smithii*, *A. cristatum*, and *Poa ampla* were planted in nurseries. Self-pollination of *Bromus inermis*, *Agropyron cristatum* and *A. smithii* was combined to obtain homozygous material, for hybridization studies. Some strains outyielded others by 3 to 6 times.

6. *Accomplishments during past year:* Field-adaptability tests were conducted on several sites in Utah using stabilized strains of *Agropyron cristatum*, *A. smithii*, *Bromus inermis*, *Dactylis glomerata*, *Festuca elatior*, *Phleum pratense*, and *Poa ampla*. Other studies to determine inherent variation in native range species and to procure desirable strains were continued.

7. *Plans for next year:* Routine observations will be continued on all selection and strains tested in the nurseries. Investigation as to the quality of the plants produced by self-pollination will be continued. Hybridization studies will be continued and the search for essential materials kept going.

8. *Date of completion:* Indefinite

9. *Assignment:* Wesley Keller, Bureau of Plant Industry; George Stewart, Advisory, Forest Service.

RR-INT
ARTIFICIAL REVEGETATION
Grazing Reseeded Ranges
February 1, 1948

GRAZING STUDIES OF RESEEDED RANGE LANDS

1. Field division: Range research

2. Work project: Artificial revegetation

3. Line project: Time, intensity, and method of grazing reseeded range lands. Cooperative SCS, Utah Agr. Exp. Station (who leads in Animal Husbandry,) and Intermountain Station, (who leads in plant studies).

4. Purpose: To determine the most practical time, intensity of use, and method of grazing reseeded range lands by cattle, and the effects on the vegetation and cattle of such treatments.

5. Review of past work: On 18 100-acre pastures at Benmore it has been found that cattle make gains fron April 15 to July 1 of 1.6 to 2.0 pounds per head per day; that utilization of around 65 percent and not to exceed 70 percent preserves the crested wheatgrass and permits it to crowd out cheatgrass; that crested wheatgrass has leaf growth 4 to 7 inches long in mid to late April when cheatgrass has single shoots 1 inch long. The grazing capacity was found in 1945 and 1946 to be approximately 7 times as great as that of nearby native range that was similar and the meat production 11 times as great.

6. Accomplishments during last year: The plan of the experiment was revised to include 24 pastures in a two-block design, the data from which lend themselves to being studied by analysis of variance methods. All pastures were grazed as nearly as possible to a uniform degree of forage utilization. Detailed data were taken on the crested wheatgrass and more general data on cheatgrass and minor species present. A conference was held with Osborne of our Washington Office on design and data to be taken.

7. Plans for next year: To revise the proposed design slightly in keeping with Washington Office suggestions and to initiate the studies involving time, intensity, and methods of grazing. Vegetation data will be taken in accordance with new design and work plans which will be revised and completed.

8. Date of completion: Indefinite

9. Assignment: Neil C. Frischknecht and George Stewart, Intermountain Station, Forest Service; Lorin E. Harris and James Bennett, Utah Agricultural Experiment Station; and Harry K. Woodward, Soil Conservation Service.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT (REVISION)
SEVIER LAKE WATERSHED

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Detailed survey of approved watersheds for preparing action program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, costs, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the Sevier Lake Watershed, Utah, and to prepare a report of these findings.

5. Review of past work: In 1940 and 1941 a survey of this watershed was completed and a report submitted. Departmental approval of the report was not obtained at that time. Before the required revisions could be made the war caused a cessation of flood control activities. Following resumption of this work in 1946 changes in policy and procedure, together with changed conditions on the watersheds and new data, made it necessary to completely revise the report in order to bring it up to date. During 1946 the field work necessary for report review was completed and hydrologic, economic, and land use data for the years 1941-1946 inclusive was analyzed. All economic data was adjusted to the 1946 monetary base and preliminary clearance was obtained from the R-4 of the Forest Service and the SCS.

6. Accomplishments during the past year: First draft of the survey report and appendix was completed early in the year. Following review in Washington the report was rewritten so as to include a rather limited number of recommended changes. Appendix material was processed in final form. The report was again reviewed after which it was rewritten in accord with proposed changes in manner of organization and presentation. At the close of the year the report was again being reviewed at Washington.

7. Plans for next year: Reproduce the report in final form following current review. Obtain final field clearance from other agencies.

8. Date of completion: Indefinite - probably early 1948.

9. Assignment: Rosa, Baudendistel, and Lobenstein.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT (REVISION)
BOISE RIVER WATERSHED

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Watershed surveys: Detailed survey of approved watersheds for preparing work program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Boise River, Idaho, drainage basin, and to prepare a report of these findings.

5. Review of past work: Work on the survey was initiated in 1938. Field work was completed and a report prepared and submitted to Washington in 1940. This report was not approved and a revision of the report was completed in 1943. Again Departmental clearance of the report was not obtained, partly on account of the effect of the war on flood control activities. Changes in Departmental policy and procedures together with recent developments on the watershed nullified much of the original work and made further revision and some additional field work necessary. The flood control program of the Corps of Engineers was analyzed as to probable effect upon the Department of Agriculture Program. Flood and damage data for the period 1943-1946 was studied and sediment discharge data on sample areas was worked out from data not previously analyzed.

6. Accomplishments during the past year: All necessary field work was completed including assistance to the Bureau of Reclamation in a sediment survey of Arrowrock Reservoir. The report and appendix was completed in preliminary review form.

7. Plans for next year: It is anticipated that some revisions of both report and appendix material will be necessary after review by the F.S. Washington Office, R-3, and the SCS, This may also be necessary following review by other agencies. After necessary reviews, the report will need to be reproduced in final form.

8. Date of completion: 1948

9. Assignment: Rosa and Lobenstein.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT
WASATCH FRONT

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Detailed survey of an approved watershed for action program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost and benefits of measures to be applied for flood control, and the prevention of accelerated soil erosion on the Wasatch Front, Utah, watershed lands, and to prepare a report of these findings.

5. Review of past work: The preliminary report on the Wasatch Front tributaries was completed in 1941 and approved in 1942. This report recommended a detailed survey and some preliminary survey work was done in 1942 and 1943, but was dropped because of the war. Upon resumption of survey work in 1946 this survey was reactivated.

6. Accomplishments during the past year: The survey outline was revised and brought up to date with emphasis upon that part of the watershed consisting mostly of frontal tributaries. Sample tributaries were selected. Surveying and mapping of plant cover-erosion categories for entire watershed was partially completed. Detailed surveys and mapping of plant cover-erosion on sample watersheds was partially completed. Additional infiltration tests were completed. A survey of road and highway damage was compiled and remedial program developed. The engineering phases of the survey program upon cropland was completed in preliminary form,

7. Plans for next year: Complete category mapping, also detailed surveys and mapping on sample tributaries. Develop structural program other than roads and highways. Collect and analyze economic data. Collect and analyze hydrologic data and develop hydrologic basis for survey report. Write report and appendix material and obtain necessary field clearance.

8. Date of completion: 1948

9. Assignment: Price, Blanch, Rosa, and Adams.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT (REVISION)
CHERRY CREEK WATERSHED

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Detailed survey of approved watersheds for preparing action program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Cherry Creek drainage basin, and to prepare a report of these findings.

5. Review of past work: A watershed survey was conducted under the leadership of the SCS and a flood control report prepared and submitted in 1941. This report was not approved at the Departmental level but suspension of flood control survey activities during the war prevented the required revision. Resumption of survey work in 1946 reactivated the survey.

6. Accomplishments during the past year: All field work needed for revision of the report was completed including that on agricultural lands which was done by personnel assigned from the SCS. Economic and land use data was collected and studied. Analysis of hydrologic data was approximately 75% completed. Appendix material was partially written.

7. Plans for next year: Complete analysis of hydrologic data, write appendix material and report. Complete drafting. Consider needed revisions after review by Forest Service and other agencies.

8. Date of completion: Preliminary draft of report to be completed March, 1948. It is expected that review by other agencies and necessary rewriting will be completed during 1948.

9. Assignment: Baudendistel, Rosa, and Thurmond.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT (REVISION)
FOUNTAIN RIVER WATERSHED

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Detailed survey of approved watersheds for preparing action program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, cost, and benefits of measures needed to be applied for flood control and prevention of accelerated soil erosion on the watershed lands of the Fountain River drainage basin, and to prepare a report of these findings.

5. Review of past work: A watershed survey was conducted under the leadership of the SCS and a flood control report prepared and submitted in 1941. This report was not approved at the Departmental level but suspension of flood control survey activities during the war prevented the required revision. Resumption of survey work in 1946 reactivated the survey.

6. Accomplishments during the past year: All field work needed for revision of the report was completed including that on agricultural lands which was done by personnel assigned from the SCS. A large flood occurred on this watershed on May 10, 1947. This flood was studied as to causes, damages suffered, and remedial measures. Economic and land use data was collected and studied. Analysis of hydrologic data was approximately 75 percent completed. Appendix material was partially written.

7. Plans for next year: Complete analysis of hydrologic data, write appendix material and report. Complete drafting. Consider needed revisions after review by Forest Service and other agencies.

8. Date of completion: Preliminary draft of report to be completed March 1948. It is expected that review by other agencies and necessary rewriting will be completed during 1948.

9. Assignment: Baudendistel, Rosa, and Thurmond.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEY AND REPORT
SOUTH PLATTE WATERSHED

1. Field division: Flood control surveys

2. Work project: Flood control surveys

3. Line project: Detailed survey of approved watershed and preparation of survey report which will form the basis for an action program.

4. Purpose: To determine the extent, nature, and cause of flood problems and the kind, costs, and benefits of measures needed to be applied for flood control and the prevention of accelerated soil erosion on the South Platte Watershed above Greeley, Colorado, and to prepare a report of these findings.

5. Review of past work: A preliminary examination of the South Platte Watershed was made in 1939 and 1940. The report which was approved in 1941 recommended a detailed survey of the watershed. But this survey was not started because of interruption of survey work by World War II.

6. Accomplishments during the past year: Authorization and funds to start the survey were received July 1, 1947. Little work was done because of the full assignment of survey personnel to other surveys which were nearing completion. The Preliminary Examination report was reviewed and discussed with the Rocky Mountain Experiment Station. Data pertaining to the watershed was secured from other agencies. A hydrologic study of Bear Creek (a tributary of the South Platte) which was recommended in the Preliminary Examination report was reviewed and discussed with the Rocky Mountain Station and the Washington Office.

7. Plans for next year: Intensive work on the survey will begin during the first quarter of the year. Preparation of a survey outline will be one of the first steps. Field work will start as soon as weather permits.

8. Date of completion: It is planned that all field work will be completed during 1948 but that analysis of data and preparation of the report will not be completed until 1949.

9. Assignment: Flood control personnel plus technicians assigned from the SCS.

RIFC - INT
FLOOD CONTROL
Watershed Survey

February 1, 1948

FLOOD CONTROL SURVEYS AND REPORTS (SCS)
QUEEN CREEK, PECOS RIVER, AND GILA RIVER WATERSHEDS

1. Field division: Flood control surveys

2. Work project: Assistance to SCS on flood control surveys for which that agency is responsible.

3. Line project: Forest Service participation in detailed surveys by the SCS on approved watersheds.

4. Purpose: To provide technical assistance to the SCS which will include the kind, cost, and benefits of measures needed to be applied on forested and associated range lands for flood control and the prevention of accelerated erosion. This assistance will be provided on watersheds assigned to the SCS for survey. Another purpose of this assistance is that of securing field review and clearance of survey reports by field departments of the Forest Service.

5. Review of past work: Work outlines for survey revision of Queen Creek and Rio Puerco Watersheds were approved. Survey assistance was provided for both watersheds and reports submitted to SCS covering national forest portion of the Queen Creek Watershed. A number of conferences were held with R-3 and the Southwestern Station concerning Forest Service interests and participation in SCS surveys.

6. Accomplishments during the past year: Final review and clearance of the Queen Creek Survey report by field offices of the Forest Service was completed. A survey outline of the Pecos River Watershed was reviewed and approved. Approximately 5 man-months of technical assistance was provided to the SCS in surveying the forested and associated range portion of this watershed. A report of this study was forwarded to the SCS. The preliminary draft of the survey report on the Pecos Watershed was reviewed and cleared with R-3 and the Southwestern Station. About 3 man-months were devoted to survey revision of the forest portions of the Upper River Watershed. Plans have been discussed with the SCS for a new survey of the Middle Rio Grande Watershed which is assigned to the SCS. This will include the Rio Puerco tributary of which some study has been made by the Forest Service.

7. Plans for next year: Forest Service review and final clearance of Pecos River Watershed survey report. Provide approximately 9 man-months assistance to SCS survey crew in study of forested and associated range portions of Middle Rio Grande Watershed and furnish SCS a report of this study. Complete report on Forest Service portion of the Upper Gila Watershed and obtain Forest Service field review and clearance.

8. Date of completion: 1948

9. Assignment: Lobenstein, Adams, and Bomberger

RE - INT
RANGE ECONOMICS
Area Studies

February 1, 1948

AREA STUDIES IN RANGE ECONOMICS

1. Field division: Forest economics.

2. Work project: Range economics.

3. Line project: Range economics.

4. Purpose: To analyze the economic problems associated with the management of western range lands and to determine the use, management practices, and distribution of public range which will result in the greatest contribution to the welfare of dependent individuals and communities.

5. Review of past work: Work in Range Economics was renewed in October of 1946 after a lapse of 3-1/2 years. The first task undertaken was a problem analysis for range economics.

6. Accomplishments during past year:
    - a. The problem analysis for the study was completed with six major problems recognized.
    - b. The economics of range reseeding and use of reseeded ranges was assigned first priority.
    - c. A working plan for a study of the above problem was developed.
    - d. Initial work on the compilation of cost of reseeding on national forest and private lands was begun.
    - e. The central Utah economic study was reviewed and plans made for publication as a station paper for land managers and workers in land economics and allied fields.
    - f. A preliminary report was made on the comparative cost of reseeding national forest and privately owned lands.

7. Plans for next year: Continue the economics of range reseeding study, completing the collection of cost data, and initiate action on the returns phase of the study. Prepare a preliminary report on the costs of range reseeding.

8. Date of completion: Indefinite

9. Assignment: Arthur H. Roth, Jr.

PUBLICATIONS
1947

I. Publications during the calendar year 1947.

A. Outside Publications (in scientific and professional journals, et.)

Croft, A. R. Some factors that influence the accuracy of water-supply forecasting in the Intermountain Region. Discussion. Trans. Amer. Geophy. Union, v. 28(3):486-491. June 1947.

______________ Utah has many areas that are real flood threats. Deseret News Weekly Magazine. Aug. 9, 1947.

Ellison, Lincoln, High on the mountain top......Where the wealth of the State begins. The Utah Farmer, January 25, 1947.

________________ Mountain range-watersheds. The Utah Farmer, February 25, 1947.

Hull, A. C., Jr. Timothy for seeding summer ranges. The Natl. Wool Grower, May 1947.

__________________ Australian sagebusting plow. Reclamation Era. December 1947.

_______________ Stiffhair wheatgrass for Intermountain sheep ranges. The Natl. Wool Grower, v. 37(12):15.

_______________ and Wm. N. Anderson. Replacing sagebrush with grass. The Natl. Wool Grower, v. 37(7).

_______________ and Jos. F. Pechanec. Aussie plow tried on sagebrush. Washington Farmer, June 19, 1947.

___________________________________ Cheatgrass--A challenge to range research. Journal of Forestry, v. 45(8):555-64.

___________________________________ Australian plow needs changes. Idaho Farmer, November 6, 1947.

___________________________________ Australian plow needs changes. Oregon Farmer, November 20, 1947.

Plummer, A. Perry. Make Utah ranges productive...Artificial seeding of range lands will help protect the livestock industry of our state. The Utah Farmer, Pt. 1, July 15; Pt. 2, August 15.

Robertson, Joseph H. Response of range grasses to different intensities of competition with sagebrush (*Artemisia tridentata* Nutt.) Ecology, V. 28(1): 1-16, 1947.

______________ Bluestem wheatgrass improves range forage. The Natl. Wool Grower, v. 37(6): 20.

Stewart George. Increasing forage by range reseeding. The Natl. Wool Grower, V. 37(1):17-19, 52. 1947.

______________ Range lands: A great resource in Alberta. The Improvement Era, v. 50(3): 146-47, 177. Illus.

______________ Mountain waters: our heritage and obligation. The Improvement Era, v. 50(7):448-50.

______________ Livestock in Weber County...A centennial episode of Utah's livestock industry. The Utah Farmer, pp. 9, 17, August 15, 1947.

______________ Tall oatgrass for range reseeding. The Natl. Wool Grower, v. 37(11).

Walters, Joel F. Utah's humid islands. UTAH, v.9(9):4-7, 24. 1947.

B. Miscellaneous Mimeographed Reports.

Craddock, G. W. Watershed management and sediment control. Proc. Assoc. Western States Engineers, pp 65-74. 1947.

Robertson, Joseph H. Season, date, and depth of planting crested wheatgrass and other grasses at lower elevations in northern Nevada. Research Paper 14, July.

II. Departmental publications scheduled for the remainder of the fiscal year 1948.

Bailey, Reed W., G. W. Craddock, and A. R. Croft. Watershed management for summer flood control in Utah. U.S.D.A. Misc. Pub, 639.

Ellison, L., *et al.* Restoring range values through management. U.S.D.A. Yearbook. 1948.

Holscher, C. E., and D. A. Spencer. Utilization of grassland crops by sheep and goats. U.S.D.A. Yearbook. 1948.

Hull, A. C., Jr., et al. Reseeding range lands in the mountain states. U.S.D.A. Yearbook. 1948.

Julander, Odell, et al. Relation of wildlife to range management. U.S.D.A. Yearbook. 1948.

Pechanec, J. F., and George Stewart. Grazing spring-fall sheep ranges of southern Idaho. U.S.D.A.

Plummer, A. Perry, et al. Range improvements through reseeding. U.S.D.A. Yearbook. 1948.

Stewart, George, et al. Forage production on range and pasture lands of the mountain states. U.S.D.A. Yearbook. 1948.

III. Manuscripts intended for departmental publication during the fiscal year 1949.

Craddock, G. W., and C. R. Hursh. Principles of watershed management. U.S.D.A. Yearbook. 1949.

Ellison, Lincoln, A. R. Croft, and Reed W. Bailey. Indicators of conditions and trend on high range-watersheds of the Intermountain region. U.S.D.A.

Hutchings, Selar S. Correlation of yearling fleece weights with fleece weights produced by the same animals at two and three years of age. Jour. Agr. Res.

______________________, and George Stewart. Management of winter sheep ranges in the Intermountain region. U.S.D.A.

Plummer, A. Perry, and J. M. Fenley. Seasonal plantings in the subalpine zone in central Utah. U.S.D.A. Circ.

Reseeding staff. Reseeding Intermountain range lands. U.S.D.A. Farmers' Bul.

Stewart, George, A. C. Hull, Jr., et al. Sagebrush eradication. U.S.D.A. Farmers' Bul.

IV. Manuscripts intended for outside publication, 1948.

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Bailey, Reed W. Reducing runoff and siltation through forest and range management. Jour. Soil and Water Conservation.

_______________, and G. W. Craddock. Watershed management for sediment control. Proceedings Denver Sedimentation Conference, Reclamation Service.

Bailey, Reed W., and A. R. Croft. The relation of watershed condition to sedimentation in northern Utah.

Craddock, G. W. Watershed Research. The Utah Magazine, Sept., 1948.

Croft, A. R. Epicycles of erosion in Bairs Canyon. Utah Acad. Sci. Arts and Letters, Proc.

__________ Evapo-transpiration losses of aspen. Jour. Forestry.

__________ Mud-rock floods in northern Utah. Jour. Geol.

__________ Summer storm characteristics. Monthly Weather Rev.

Lull, Howard W. A history of forest influences research. Sci. Monthly.

______________ Artificial snow drifting. Jour. Forestry.

______________ Site-class flood potentials. Jour. Forestry.

Packer, Paul E. Evapo-transpiration losses of grasslands. Jour. Forestry.

___________ Runoff and erosion factors. Trans. Amer. Geophys. Union.

Reseeding

Blaisdell, J. P., and R. M. Hurd. Influence of sagebrush competition on establishment of reseeded species. Ecology

Fenley, J. M. Erosion control and forage uses of oldman wormwood. Utah Farmer.

____________ Reseeding opportunities in Nevada. Nevada Extension Service Bul.

Hull, A. C., Jr., Plant development and seasonal yields of cheatgrass and reseeded grasses in southwestern Idaho. Amer. Soc. Agron. Jour.

____________ Season, depth, and row spacing for planting grasses on southern Idaho range lands. Amer. Soc. Agron. Jour.

____________, and George Stewart. Replacing cheatgrass by seeding with perennial grass on Idaho range lands. Amer. Soc. Agron. Jour.

Hurd, R. M. Reseeding Nevada range lands. Nevada Agr. Col. Ext. Bul.

________________ Grazing crested wheatgrass pastures in Nevada. Jour. Range Management.

Plummer A. Perry. Forage species and strains. Amer. Soc. Agron. Jour.

________________, and N. C. Frischknecht. Treatment of seeds of ricegrass. Amer. Soc. Agron. Jour.

Stewart, George. Investigations and programs in range reseeding for the Intermountain region. Sci. Monthly.

________________ Range reseeding research. The Utah Magazine. Sept. 1948.

________________ Accomplishments in range reseeding. Natl. Wool Grower.

________________, and A. C. Hull, Jr. Cheatgrass--an ecological intruder in southern Idaho. Ecology.

Grazing Management

Blaisdell, J. P., and J. F. Pechanec. Plant vigor as affected by date of top removal. Plant Physiology.

Holscher, C. E., A. C. Wiese, and C. W. Hodgson. Variations in chemical content of certain range plants. Idaho Expt. Sta. Bul.

Hutchings, Selar S. Correlation of fleece weight produced by ewes at one, two, and three years of age. Natl. Wool Grower.

________________ Deer utilization on oakbrush ranges of central Utah.

Julander, Odell. Deer-cattle competition. Jour. Forestry.

________________, and J. G. Smith. Deer-sheep competition. Jour. Forestry.

________________, *et al*. The big-game livestock range problem in Utah. Utah State Fish and Game Dept. Leaflet.

Smith, J. G. Observations on deer forage habits in Utah. Jour. Wildlife Management.

Range Economics

Roth, A. H., Jr. Evaluation of public range-watersheds. West. Farm Economics Assoc. Proc.

____________________. Needed: A method of western mountain land valuation. Jour. Land and Public Utility Economics.

Timber Management

Curtis, James D. Animals that eat ponderosa pine seed. Jour. Wildlife Management.

____________________. Utah Aspen comes of age. Amer. Forests.

General

Fenley, J. M. Dune control at Les Landes, France. Jour. Forestry.

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STATION PERSONNEL - C. Y. 1947

ADMINISTRATION

Reed W. Bailey	Director
Irene P. Muir	Secretary
Joel F. Walters	Editor
Walter E. Mann	Adm. Assistant
Marguerite A. Israelson	Clerk
Leona H. O'Donnell	Clerk
Lillian Eastman	Clerk
Grant S. Williams	Clerk
Kathryn E. Ogden	Stenographer
Bar Dee T. Campbell	Stenographer
Ruth H. Muse	Stenographer
Marion R. Pearson	Stenographer
Harry W. Pledger	Foreman C&M

RANGE INVESTIGATIONS

Grazing Management

Lincoln Ellison	Range Conservationist (Research)
Clark E. Holscher	Range Conservationist (Research)
Selar S. Hutchings	Range Conservationist (Research)
Odell Julander	Range Conservationist (Research)
James P. Blaisdell	Range Conservationist (Research)
Justin G. Smith	Range Conservationist (Research)
Alvin T. Bleak	Range Conservationist (Research)
Jack Major	Range Conservationist (Research
Paul E. Hansen	Agricultural Aid
James R. Gray	Agricultural Aid
Evan R. Johnson	Clerk-Stenographer

Range Reseeding

George Stewart	Range Conservationist (Research)
Alvin C. Hull, Jr.	Range Conservationist (Research)
A. Perry Plummer	Range Conservationist (Research)
Richard M. Hurd	Range Conservationist (Research)
John M. Fenley	Range Conservationist (Research)
Neil C. Frischknecht	Range Conservationist (Research)
John W. Warren	Agricultural Aid

FOREST AND RANGE ECONOMICS

Arthur H. Roth, Jr.	Agricultural Economist

FOREST AND RANGE INFLUENCES

George W. Craddock	Conservationist (Forester)
A. Russell Croft	Conservationist (Forester)
Paul E. Packer	Conservationist
Howard W. Lull	Conservationist
Richard B. Marston	Conservationist
Alden Blain	Agricultural Aid
Robert W. Richman	Agricultural Aid

FLOOD CONTROL SURVEYS

Henry L. Lobenstein	Forester
Martin E. Baudendistel	Conservationist
John A. Adams	Engineer (Civil)
Elon H. Bomberger	Conservationist
William E. Murray	Forester
Olaf C. Olson	Soil Scientist
Harold H. Price	Conservationist
J. Marvin Rosa	Hydrologist
Albert R. Blanch	Conservationist (Flood)
J. Smith Adair	Geologist
George W. Carlson	Forester
Merle H. Tigerman	Forester (Range)
Byron F. Thurmond	Cartographic Engineer
Richard W. Payne	Engineering Draftsman

FOREST MANAGEMENT INVESTIGATIONS

James D. Curtis	Silviculturist